PATENT

Attorney Docket No. 20067US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

MARKUS REITER

Serial No. 10/711,842

Filed: October 8, 2004

For: Low-Noise Chainwheel

Group Art Unit 3657

Examiner: Thomas W. Irvin

APPEAL BRIEF

Commissioner For Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In regard to the above-identified application, Appellant submits this Appeal Brief.

I. REAL PARTY OF INTEREST

The real party in interest is SRAM Deutschland GmbH. SRAM Deutschland GmbH's right to take action in the subject application was established by virtue of an Assignment from the Markus Reiter to SRAM Deutschland recorded at Reel/Frame 015566/0305.

II. RELATED APPEALS AND INTERFERENCES

The undersigned legal representative of Appellant hereby confirms that there are no known appeals or interferences relating to the present application, or any parent application, which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

III. STATUS OF CLAIMS

Claims 1-3, 5 and 7-24 are pending in the application. Claims 4 and 6 have been cancelled. Claims 10, 11, 13, 14 and 17-22 have been withdrawn. No claims are allowed. Claims 1-3, 5, 7-9, 12, 15, 16 and 24 have been rejected. Rejection of claims 1-3, 5, 7-9, 12, 15, 16 and 24 is being appealed.

IV. STATUS OF THE AMENDMENTS

No amendments have been filed after the office action dated December 28, 2009.

V. SUMMARY OF CLAIMED SUBJECT MATTER

The claims are generally directed toward a chainwheel assembly engageable with a chain. Claim 1 is an independent claim. No claim includes a means plus function elements as permitted by 35 U.S.C. 112, paragraph six.

Claim 1 as currently pending recites a chainwheel assembly including a plurality of chainwheels engageable with a chain 12 having successive alternating pairs of inner link plates 13 and outer link plates 14 connected by pins 16, the pins 16 surrounded by rollers 15 (paragraph 37, lines 1-6). The chainwheel assembly includes at least one smaller

chainwheel 11 having a plurality of teeth spaced about its circumference and at least one larger chainwheel 1 having a plurality of teeth spaced about its circumference. The larger chainwheel 1 and the smaller chainwheel 11 are oriented relative to each other such that a distance between a center of the chain roller 34 positioned between a pair of adjacent teeth on the larger chainwheel 1 and the center of the chain roller 32 between a pair of adjacent teeth on the smaller chainwheel 11 is substantially an integer multiple of the chain pitch (paragraph 37, lines 7-11). At least a first tooth 3 of the pair of adjacent teeth 3, 4 on the larger chainwheel 1 includes a first lateral recess 2 disposed on a front face 36 of the larger chainwheel 1 facing the smaller chainwheel 11 to allow the chain 12 to move from the smaller chainwheel 11 towards the larger chainwheel 1 (paragraph 45, lines 6-8 and FIGS. 6 and 7). The first lateral recess 2 has a first run-on ramp 7 configured to lift the outer link plate 14 in a radial direction when the outer link plate 14 is positioned laterally at the first tooth 3 (paragraph 45, lines 10-13 and FIGS. 6 and 7). At least a second tooth 4 of the pair of adjacent teeth 3, 4 is disposed adjacent to the first tooth 3 opposite the drive rotation 10 direction including a second recess 2 disposed on the front face of the larger chainwheel 1 facing the smaller chainwheel 11 to allow the chain 12 to move from the smaller chainwheel 11 towards the larger chainwheel 1. The second recess 2 has a second run-on ramp 7 configured to lift the outer link plate 14 in the radial direction when the outer link plate 14 is positioned laterally at the second tooth (paragraph 45, lines 13-15 and FIGS. 6 and 9).

VI. GROUND OF REJECTION TO BE REVIEWED ON APPEAL

1. Whether claims 1-3, 5, 7-9, 12, 15 and 16 are anticipated by Kamada (US 6,340,338) under 35 U.S.C. 102(b).

2. Whether claims 1-3, 5, 7, 8, 12, 15, 16 and 24 are anticipated by Yahata (US 2002/0086753) under 35 U.S.C. 102(b).

VII. ARGUMENT

102(b) Rejection of claims 1-3, 5, 7-9, 12, 15 and 16

Claims 1-3, 5, 7-9, 12, 15 and 16 were rejected under 35 U.S.C. 102(b) as being anticipated by Kamada (US 6,340,338). Kamada fails to disclose the structure of first and second run-on ramps positioned respectively at first and second adjacent teeth, as claimed in the present invention. The claimed structural pairing of these run-on ramps at adjoining first and second teeth accommodates the positioning of an outer chain link during a shifting operation at either the first or second tooth. The Federal Circuit requires "[t]he Patent and Trademark Office ('PTO') determines the scope of claims in patent applications not solely on the basis of the claim language, but upon giving claims their broadest reasonable construction 'in light of the specification as it would be interpreted by one of ordinary skill in the art." Philips v. AWH Corp., 415 F.3d 1303, 1316-17 (Fed Cir. 2005). On the contrary, Examiner's interpretation of the claim feature "run-on ramp" is inconsistent with the specification. The structural limitation of a run-on ramp is described not only in the specification at Paragraph 11("During a shift operation, when an outer link plate arrives next to the reference tooth, it braces itself against the run-on ramp, . . .") but also in the FIGS. 7 and 9. On the contrary, Kamada [as further described in FIG. 1 of referenced US 4,889,521, at Kamada col. 10, lines 59-61] merely discloses a single run-on ramp disposed proximate guide portion termination 4d for receiving an outer link plate. There is no second run-on ramp in chain guide 4, merely an initial edge 4b, an inside surface 4a and a stepped portion 4b (in referenced US '521 FIG. 1), none of which form a second run-on ramp configured to permit the arriving outer link plate to brace itself against the run-on ramp and thereby lift the outer link plate in a radial direction.

Further, Examiner states the following in the office action dated December 2, 2009 at page 6:

> As previously stated, in response to applicant's argument that Kamada fails to disclose two run-on ramps configured to lift the outer link plate of a

> chain, a recitation of the intended use of the claimed invention must result in a structural difference between the claimed invention and the prior art in order to patentably distinguish the claimed invention from the prior art. If the prior art structure is capable of performing the intended use, then it meets the claim. In this case, the examiner believes that Kamada's recesses are understood to include run-on ramps that could lift the outer link plate of a chain as understood from the claim.

The Federal Circuit has stated that "the [prior art] reference must describe the applicant's claimed invention sufficiently to have placed a person of ordinary skill in the field of the invention in possession of it." *In re Spada*, 911 F.2d 705, 708 (Fed. Cir. 1990). One skilled in the art would understand that features 4a, 4b and 4e of Kamada are structurally distinct from chain guide 4 and therefore cannot be run-on ramps as claimed in the present invention.

Claims 2-3, 5, 7-9, 12, 15 and 16 were rejected as claim 1 under 35 U.S.C. 102(b). Since claims 2-3, 5, 7-9, 12, 15 and 16 depend directly or indirectly from and contain all the limitations of the claim 1, they are felt to overcome the 102 rejection in the same manner as claim 1.

<u>102(b) rejection of claims 1-3, 5, 7, 8, 12, 15, 16 and 24</u>

Claims 1-3, 5, 7, 8, 12, 15, 16 and 24 were rejected under 35 U.S.C. 102(b) as being anticipated by Yahata (2002/0086753). Yahata discloses a chamfered portion 48, smoothly contoured to resist trapping mud (FIG. 6). Accordingly, chamfered portion 48 fails to allow the outer link plate to be positioned laterally at the first tooth and fails to lift the outer link plate in a radial direction when the outer link plate is positioned laterally at the first tooth, as claimed in the present invention. As noted above, Examiner's interpretation of the claim feature "run-on ramp" is inconsistent with the specification. Examiner merely points to an indented feature on the front face of the Yahata chainwheel, not to a run-on ramp. Accordingly, Examiner has failed to locate the claimed structural feature "run-on ramp" in Yahata or the associated limitation of lifting the outer link plate in a radial direction.

Further, Examiner states the following in the office action dated December 2, 2009 at page 7:

> As state above, in response to applicant's argument that recesses E and D of Yahata are not configured to lift the outer link plate of a chain, a recitation of the intended use of the claimed invention must result in a structural difference between the claimed invention and the prior art in order to patentably distinguish the claimed invention from the prior art. If the prior art structure is capable of performing the intended use, then it meets the claim. In this case, the examiner believes that Yahata's recesses are understood to include run-on ramps that could lift the outer link plate of a chain as understood from the claim.

As stated above, Federal Circuit has stated that "the [prior art] reference must describe the applicant's claimed invention sufficiently to have placed a person of ordinary skill in the field of the invention in possession of it." *In re Spada*, 911 F.2d 705, 708 (Fed. Cir. 1990). One skilled in the art would not understand the chambers 48 of Yahata to be run-on ramps as claimed in the present invention.

Claims 2-3, 5, 7, 8, 12, 15, 16 and 24 were rejected as claim 1 under 35 U.S.C. 102(b). Since claims 2-3, 5, 7, 8, 12, 15, 16 and 24 depend directly or indirectly from and contain all the limitations of the claim 1, they are felt to overcome the 102 rejection in the same manner as claim 1.

VIII. CLAIMS APPENDIX

1. A chainwheel assembly including a plurality of chainwheels engageable with a chain having successive alternating pairs of inner link plates and outer link plates connected by pins, the pins surrounded by rollers, the chainwheel assembly comprising:

at least one smaller chainwheel having a plurality of teeth spaced about its circumference; and

at least one larger chainwheel having a plurality of teeth spaced about its circumference,

the larger chainwheel and the smaller chainwheel oriented relative to each other such that a distance between a center of the chain roller positioned between a pair of adjacent teeth on the larger chainwheel and the center of the chain roller between a pair of adjacent teeth on the smaller chainwheel is substantially an integer multiple of the chain pitch,

at least a first tooth of the pair of adjacent teeth on the larger chainwheel including a first lateral recess disposed on a front face of the larger chainwheel facing the smaller chainwheel to allow the chain to move from the smaller chainwheel towards the larger chainwheel, the first lateral recess having a first run-on ramp configured to lift the outer link plate in a radial direction when the outer link plate is positioned laterally at the first tooth,

at least a second tooth of the pair of adjacent teeth disposed adjacent to the first tooth opposite the drive rotation direction including a second recess disposed on the front face of the larger chainwheel facing the smaller chainwheel to allow the chain to move

from the smaller chainwheel towards the larger chainwheel, the second recess having a second run-on ramp configured to lift the outer link plate in the radial direction when the outer link plate is positioned laterally at the second tooth .

2. The chainwheel assembly of claim 1 wherein the first run-on ramp extends to a tooth root of the second tooth.

3. The chainwheel assembly of claim 2 wherein the first run-on ramp extends, at the tooth root, into the outer periphery of the larger chainwheel.

5. The chainwheel assembly of claim 3 wherein the larger <u>chainwheel</u> includes a third tooth disposed adjacent the second tooth opposite the drive rotation direction includes a run-out chamfer disposed on the front face of the larger chainwheel, the run-out chamfer extending obliquely backward opposite to the drive rotation direction to provide a shifting lane for the link plate.

7. The chainwheel assembly of claim 1 wherein the first recess has a depth approximately equal to a thickness of the link plate.

8. The chainwheel assembly of claim 1 wherein the second tooth includes a deflection chamfer directed toward the smaller chainwheel to prevent the second tooth from capturing the chain.

9. The chainwheel assembly of claim 8 wherein the deflection chamfer is pronounced on an edge of the second tooth pointing in the drive rotation direction and tapers off toward a back of the tooth on an opposite edge of the second tooth.

12. The chainwheel assembly of claim 1 wherein the first tooth and the second tooth each include a deflection chamfer directed toward the smaller chainwheel to prevent the first tooth and the second tooth from capturing the chain.

15. The chainwheel assembly of claim 1 wherein tooth backs of the first tooth and the second tooth are located directly on a back face of the larger chainwheel facing the next larger chainwheel such that at an end of the shifting operation, the inner link plate has traveled a maximum axial shifting distance before it slides over the tooth back before the chain capture tooth.

16. The chainwheel assembly of claim 1 wherein the first, second and third teeth comprise tips that are chamfered on the front face such that at the end of the shifting operation, the inner link plate does not abruptly jump over the tooth back of the respective tooth.

24. The chain of claim 1, wherein the first recess is separate from the second recess.

IX. EVIDENCE APPENDIX

Enclosed please find copies of the Kamada, United States Patent No. 6,340,338, reference and the Yahata, United States Patent Application No. 2002/0086753, reference relied upon by Examiner as to the grounds of rejection to be reviewed upon appeal. Also included is a copy of the United States Patent No. 4,889,521 which is referred to by the Kamada reference.

X. RELATED PROCEEDINGS APPENDIX

None

XI. CLOSING REMARKS

For the foregoing reasons, Appellants submit that the rejections of claims 1-3, 5, 7-9, 12, 15, 16 and 24 under 35 U.S.C. 102(b) are improper, and that claims 1-3, 5, 7-9, 12, 15, 16 and 24 are, therefore, patentable. Accordingly, Appellants respectfully request that the rejections of Examiner be reversed.

Respectfully submitted,
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US006340338B1

(12) United States Patent
Kamada

(10) Patent No.: US 6,340,338 B1
(45) Date of Patent: Jan. 22, 2002

(54) **BICYCLE SPROCKET**

(75) Inventor: **Kenji Kamada**, Osaka (JP)

(73) Assignee: **Shimano Inc.**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/661,201**

(22) Filed: **Sep. 13, 2000**

(51) **Int. Cl.**[7] **F16H 55/30**
(52) **U.S. Cl.** **474/160**; 474/152
(58) **Field of Search** 474/148, 152, 474/157, 158, 160

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,889,521	A		12/1989	Nagano	
4,946,425	A	*	8/1990	Bühlmann	474/80
5,085,620	A	*	2/1992	Nagano	474/152
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6,015,159	A		1/2000	Matsuo	
6,045,472	A		4/2000	Sung et al.	
6,073,061	A		6/2000	Kimura	
6,139,456	A	*	10/2000	Lii et al.	474/152

FOREIGN PATENT DOCUMENTS

EP	0 689 988 B1	11/1997
JP	2-189296	7/1990

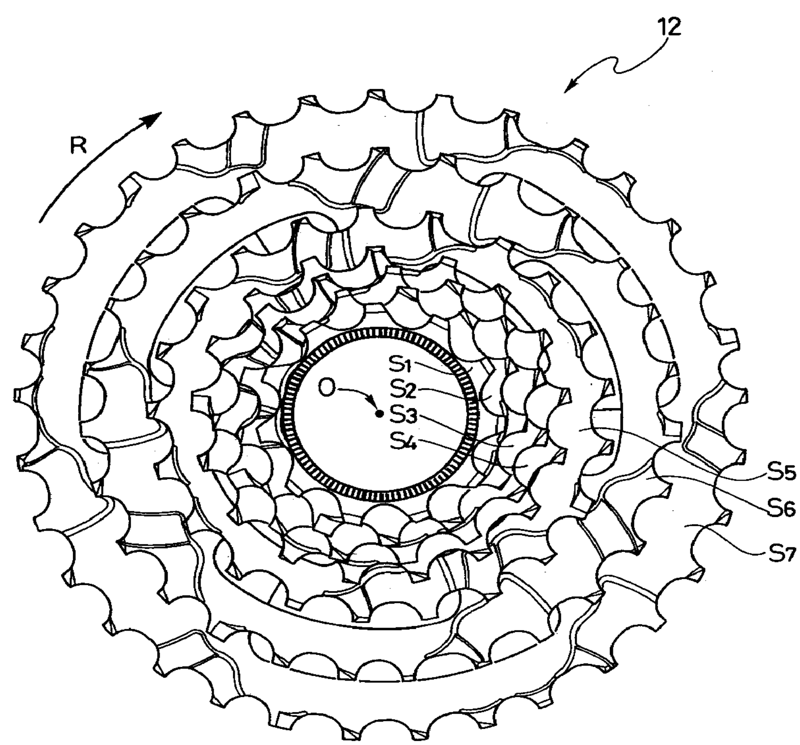
* cited by examiner

Primary Examiner—David A. Bucci
Assistant Examiner—Timothy McAnulty
(74) *Attorney, Agent, or Firm*—Shinjyu Global IP Counselors, LLP

(57) **ABSTRACT**

A sprocket assembly for a bicycle is provides with at least one large sprocket and at least one small sprocket. The large sprocket is modified to allow a bicycle chain to move smoothly from the large sprocket to the small sprocket during an up shift operation. The large sprocket basically has a sprocket body with a first axial side and a second axial side, and a plurality of circumferentially spaced teeth extending radially and outwardly from an outer periphery of the sprocket body. The teeth of the sprocket include a plurality of up shift teeth. The up shift teeth has at least a first up shift tooth, a second up shift tooth located adjacent the first up shift tooth and a third up shift tooth located adjacent the second up shift tooth. The first, second and third up shift teeth are dimensioned to maintain alignment of a bicycle chain to prevent an up shift of the chain when an outer link plate of the bicycle chain meshes with the second up shift tooth, and to permit an up shift the bicycle chain when an inner link plate meshes with the second up shift tooth along a first up shift path.

48 Claims, 20 Drawing Sheets



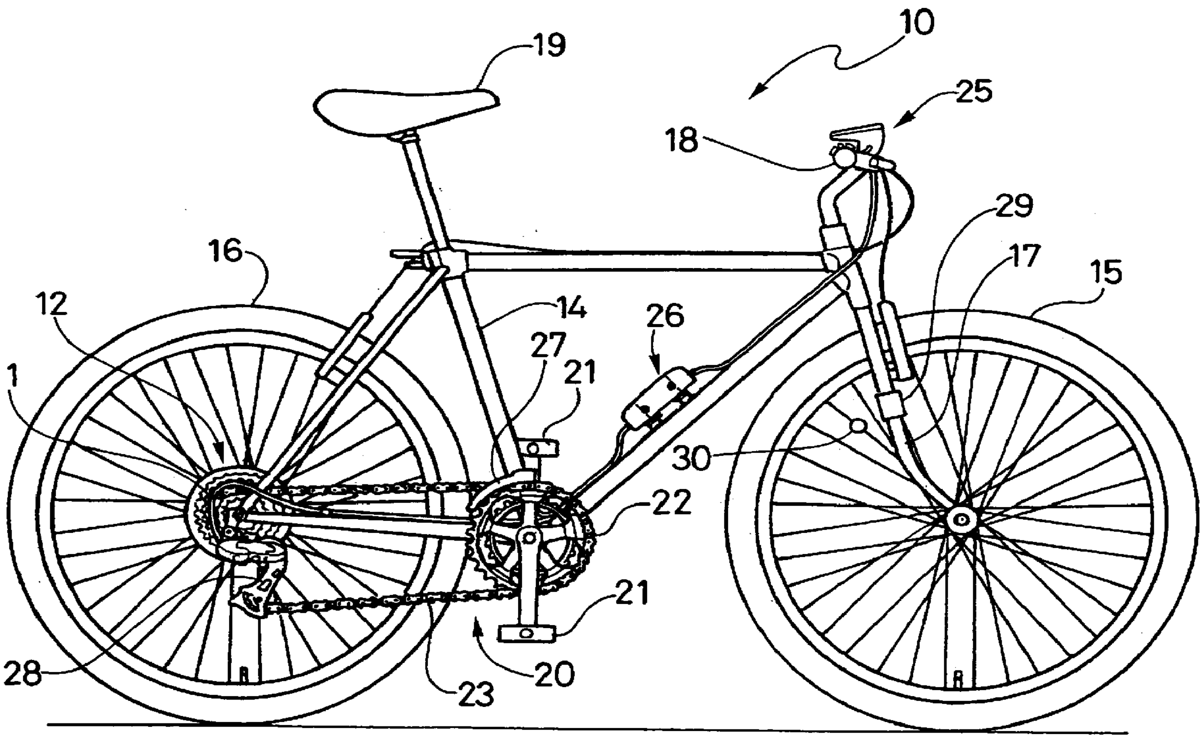

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FIG. 1A

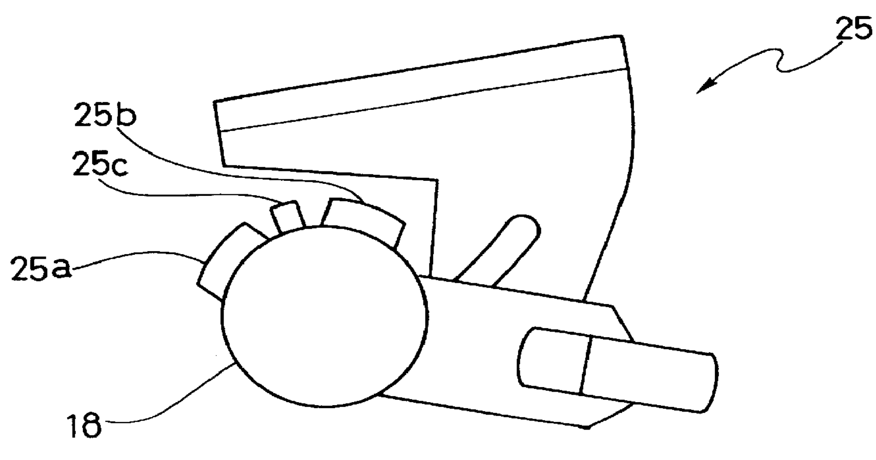
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FIG. 1B

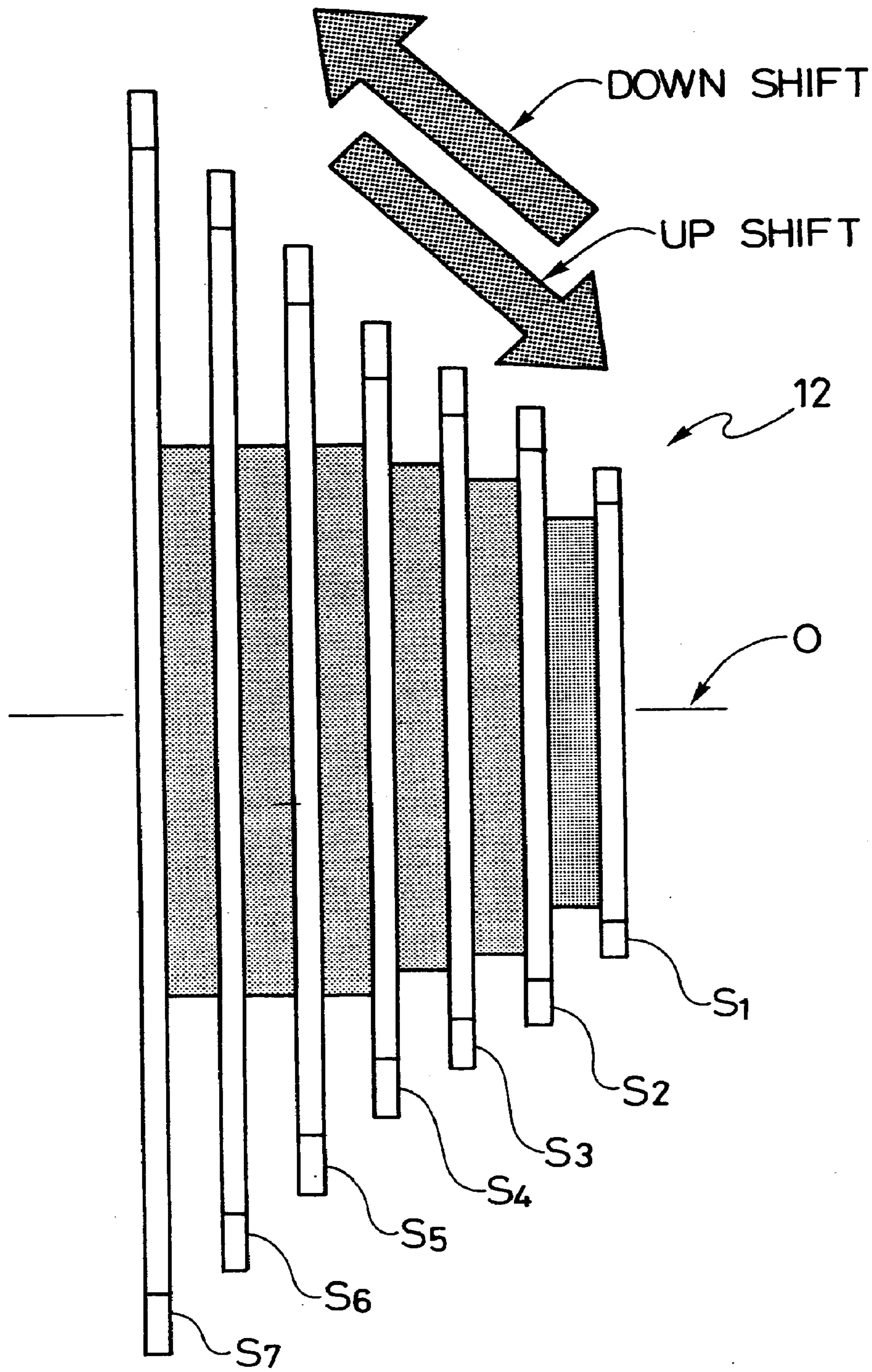

FIG. 2

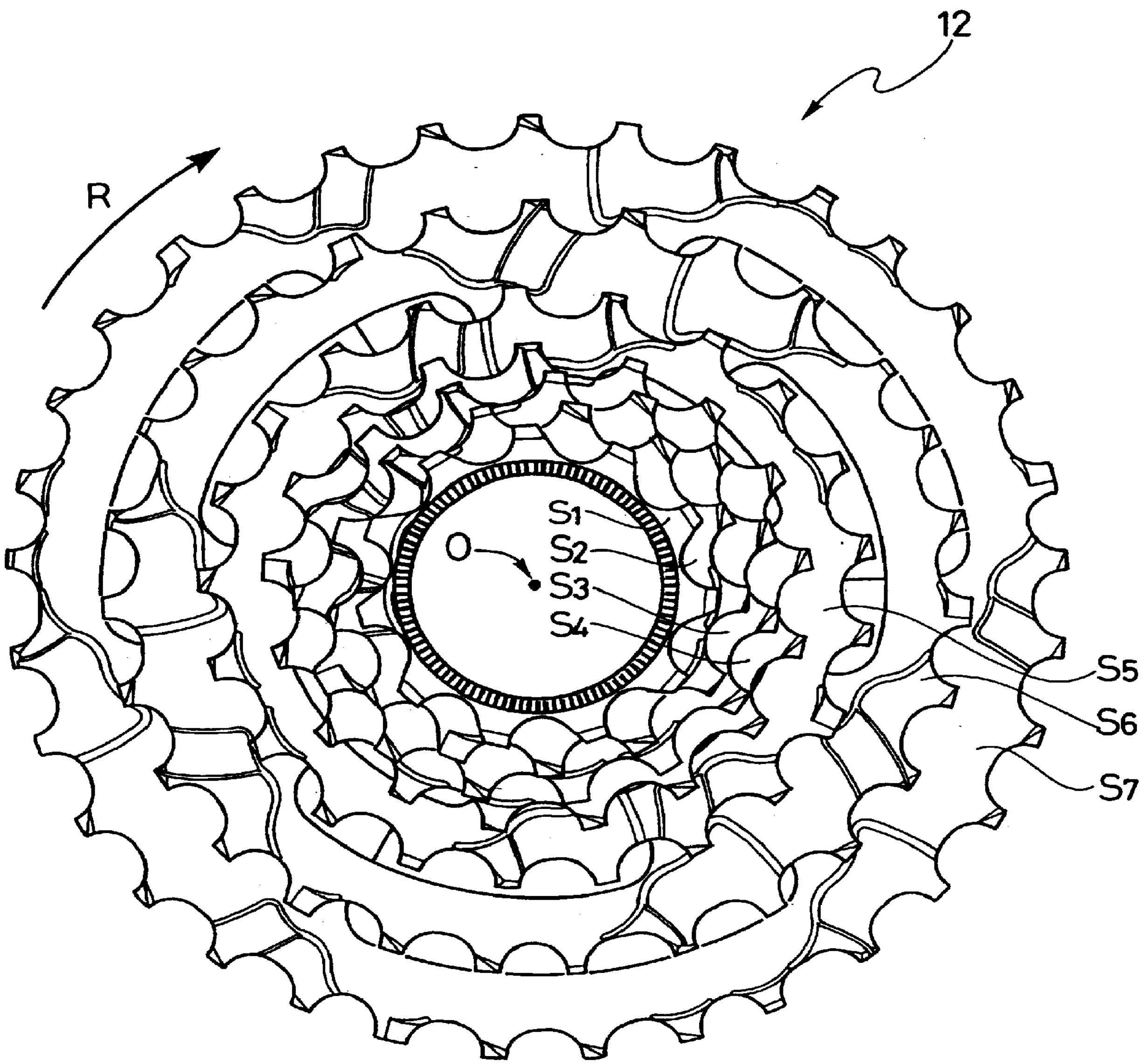

FIG. 3

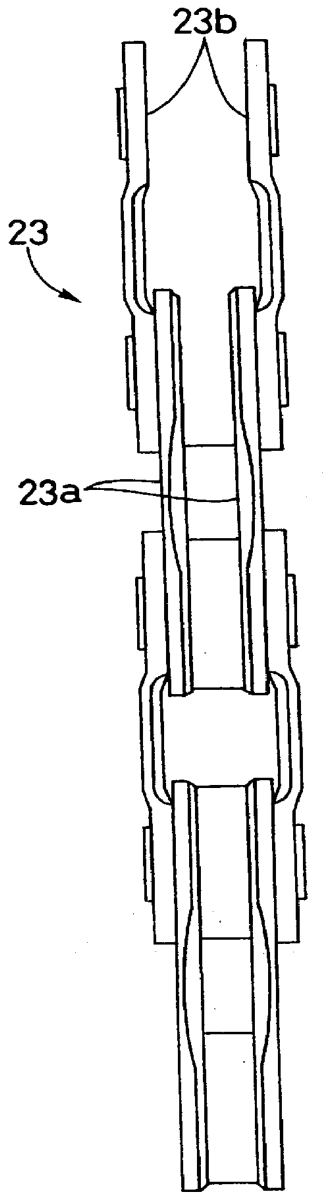

FIG. 4

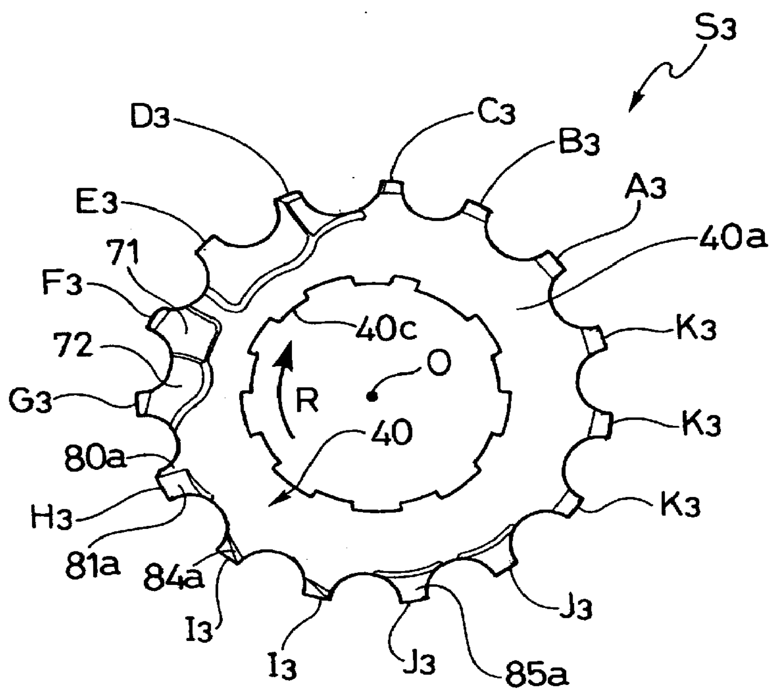

FIG. 5

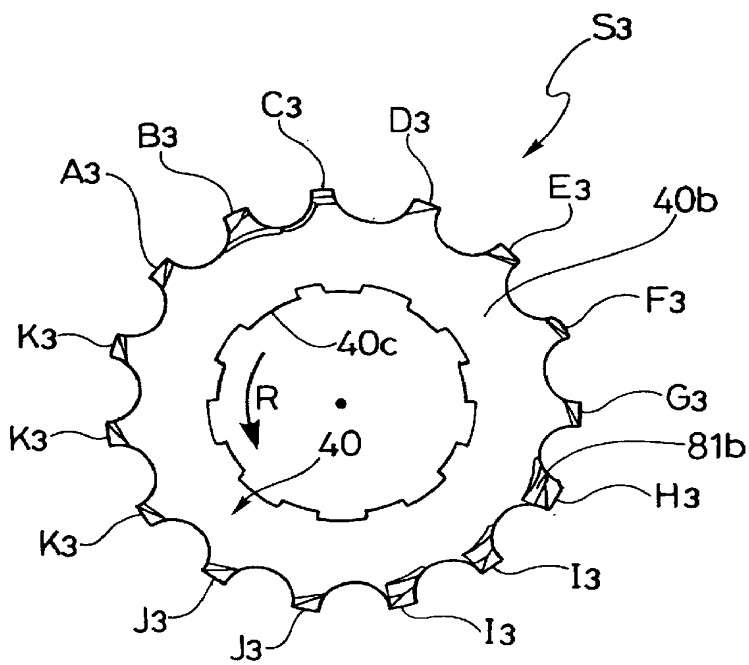

FIG. 6

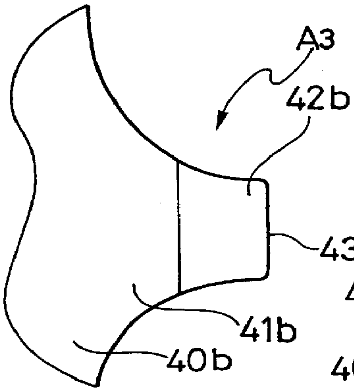

FIG. 7A

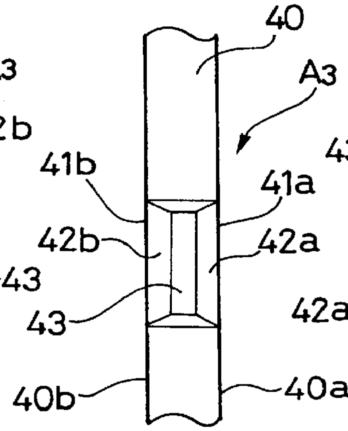

FIG. 7B

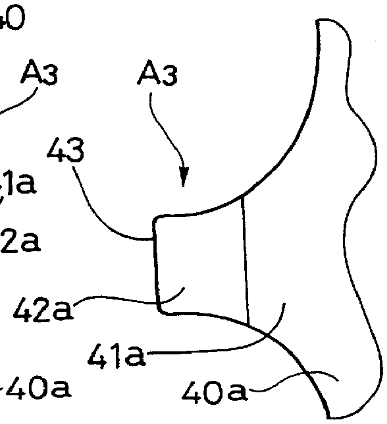

FIG. 7C

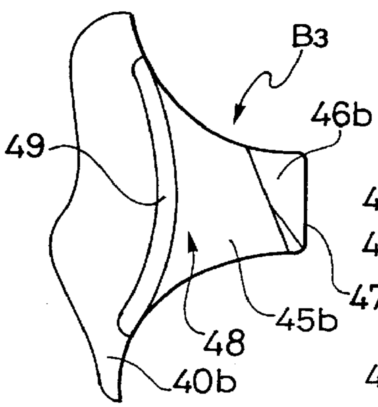

FIG. 8A

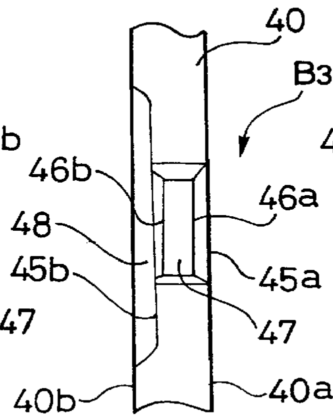

FIG. 8B

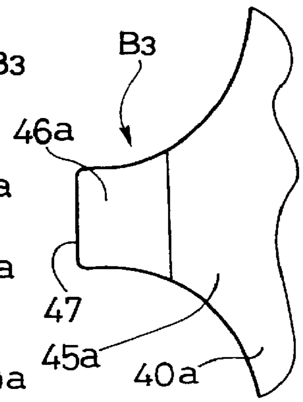

FIG. 8C

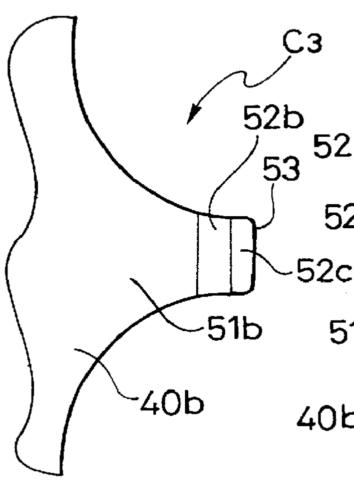

FIG. 9A

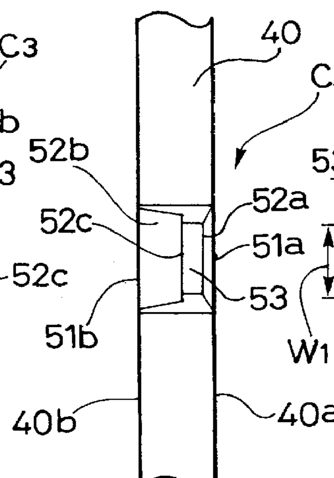

FIG. 9B

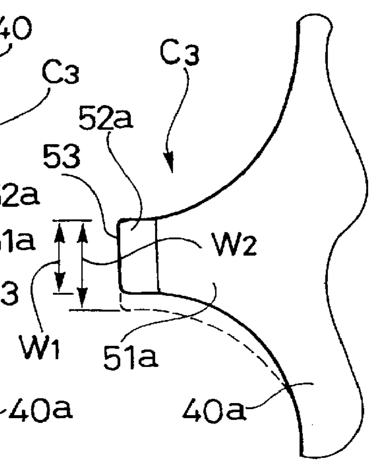

FIG. 9C

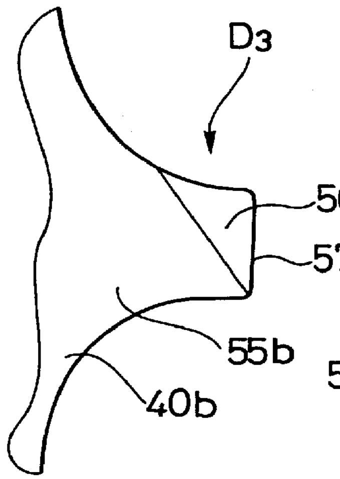

FIG. 10A

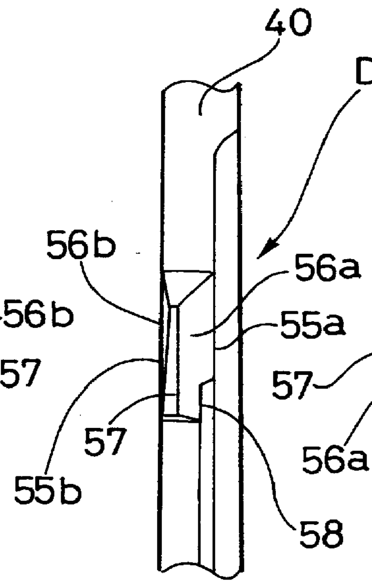

FIG. 10B

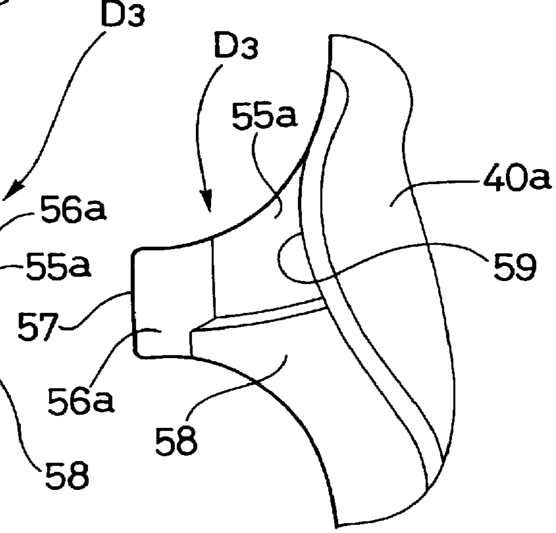

FIG. 10C

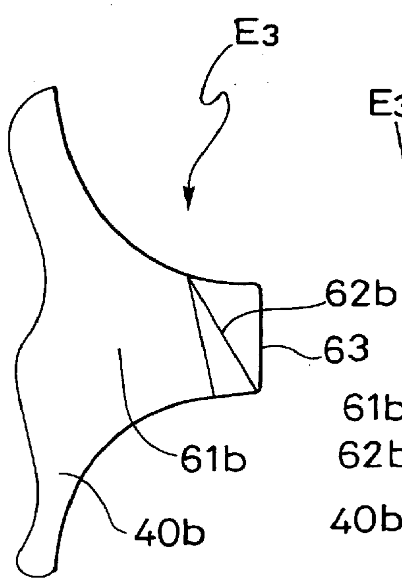

FIG. 11A

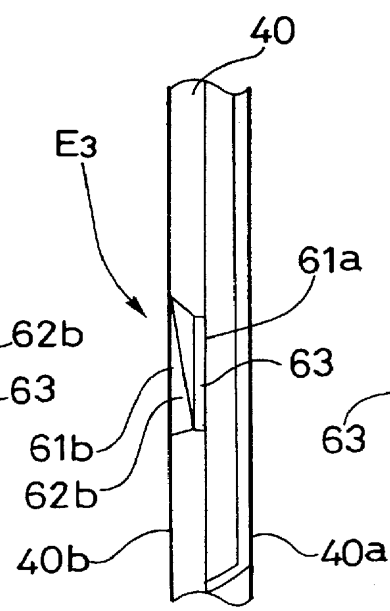

FIG. 11B

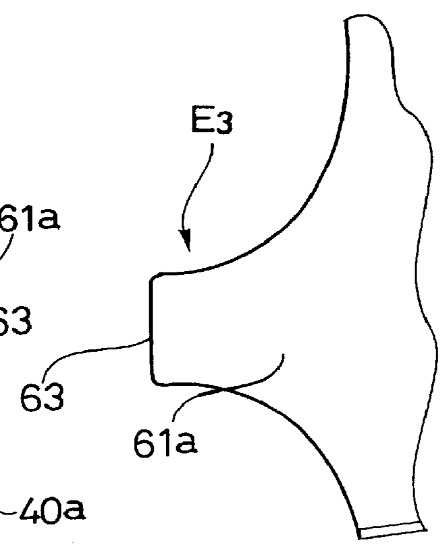

FIG. 11C

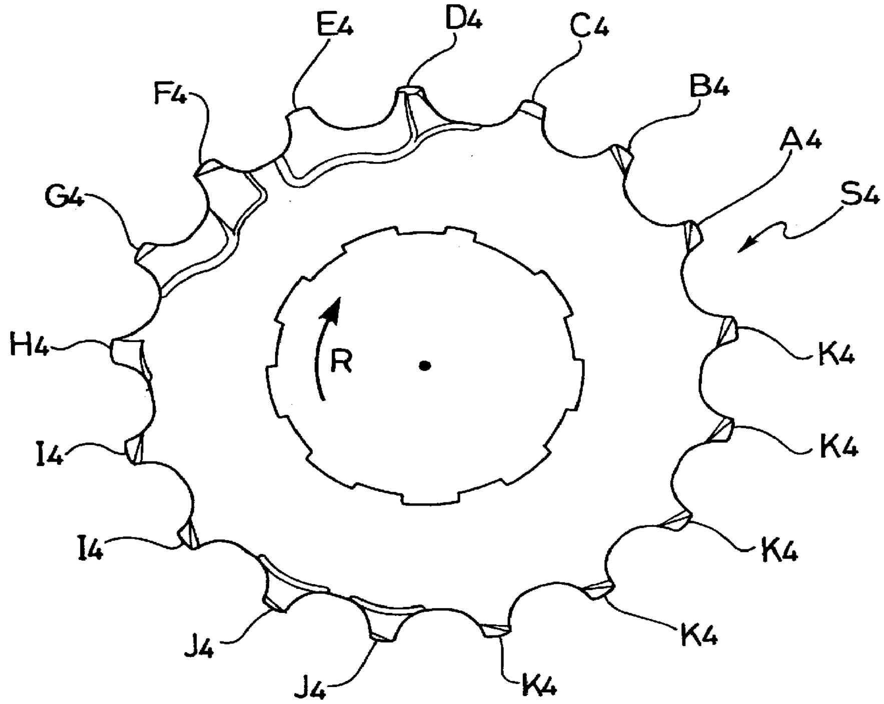
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FIG. 12

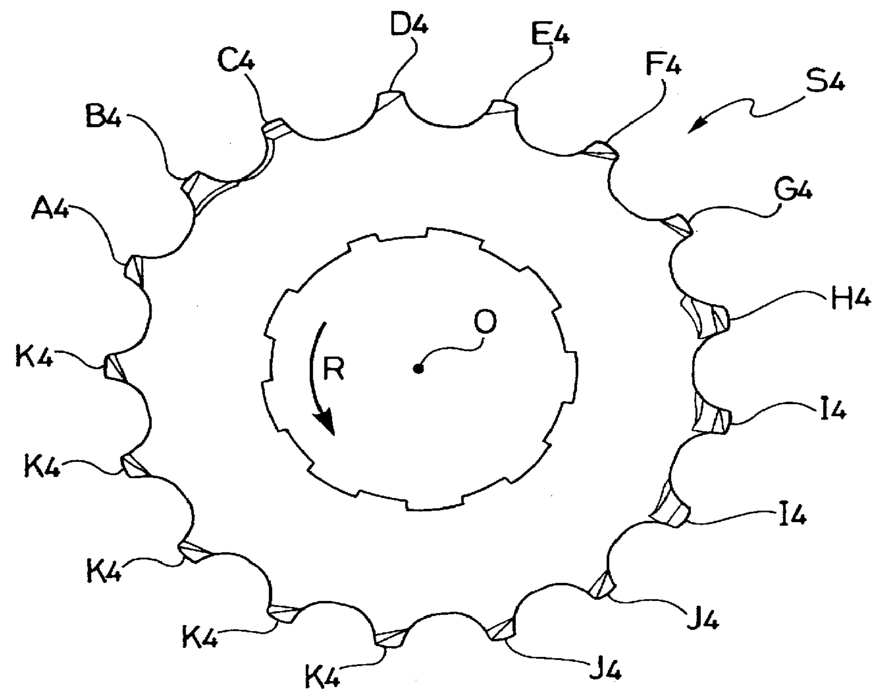
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FIG. 13

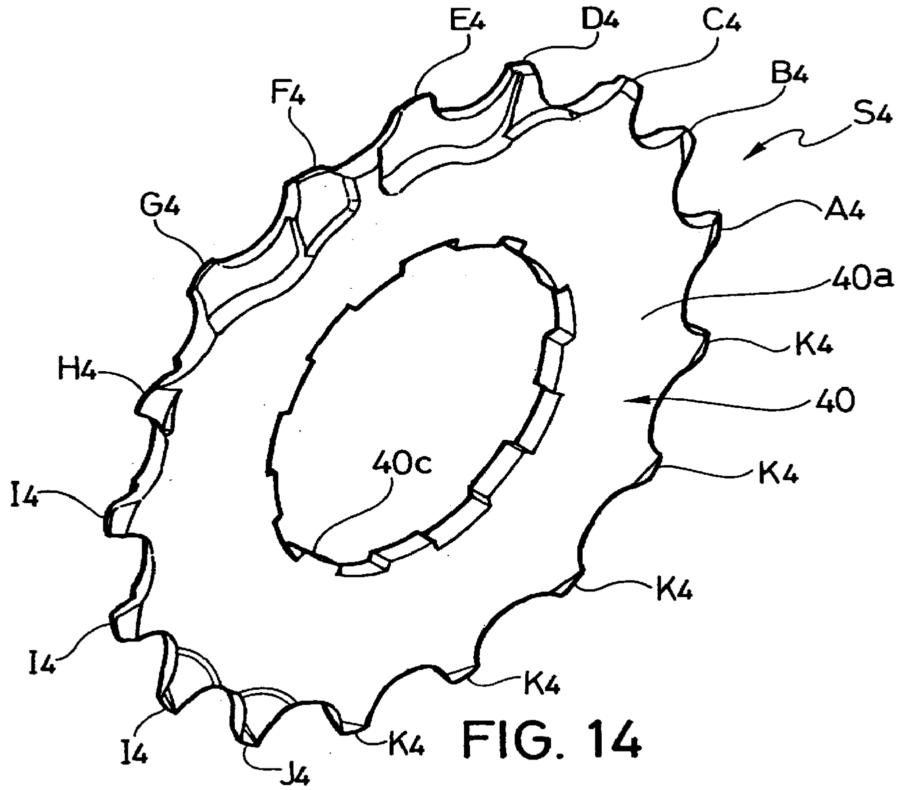
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FIG. 14

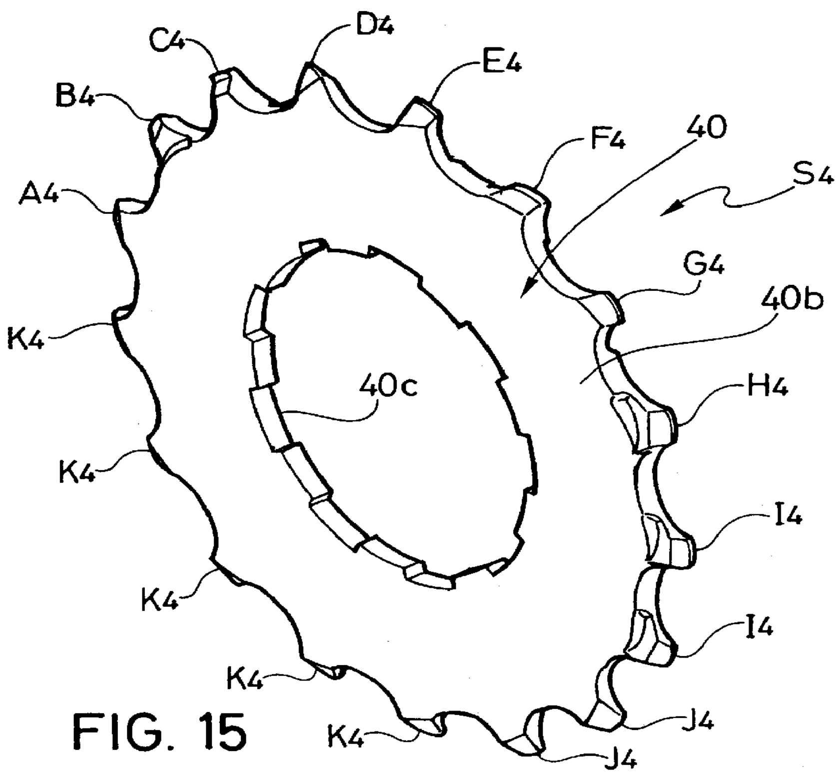
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FIG. 15

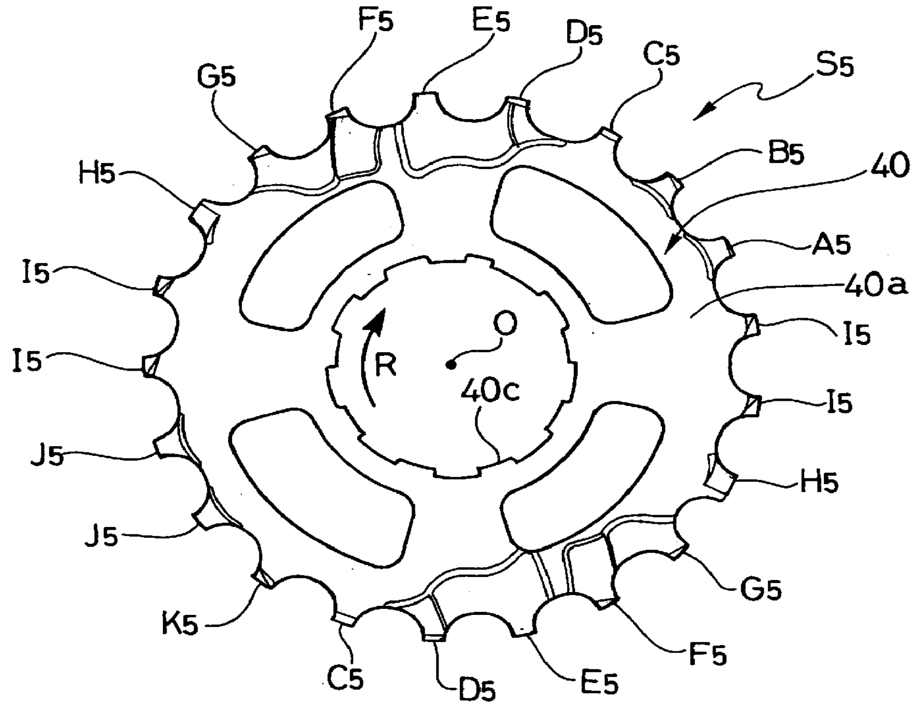
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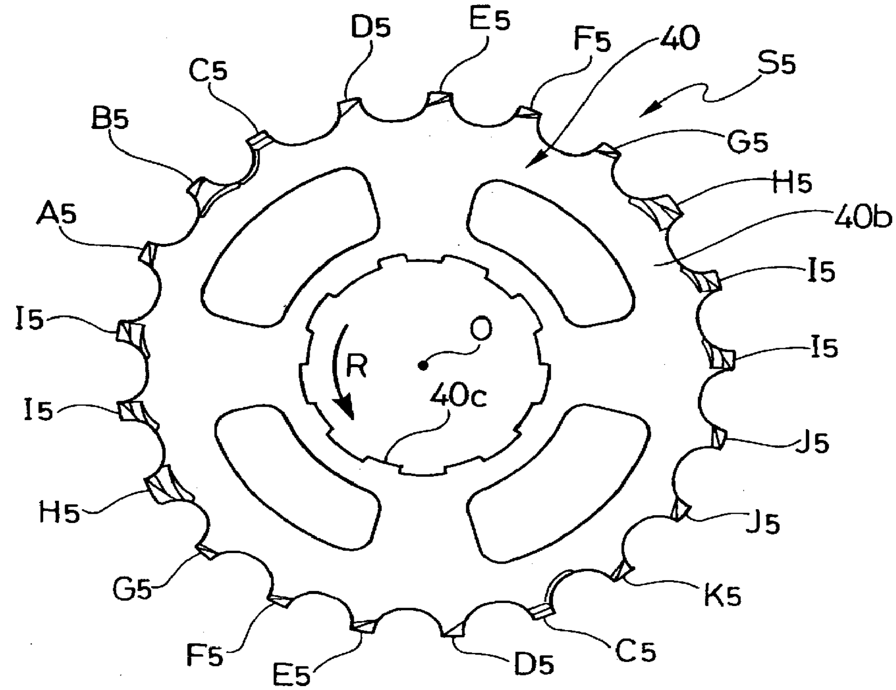
FIG. 16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G5
K5
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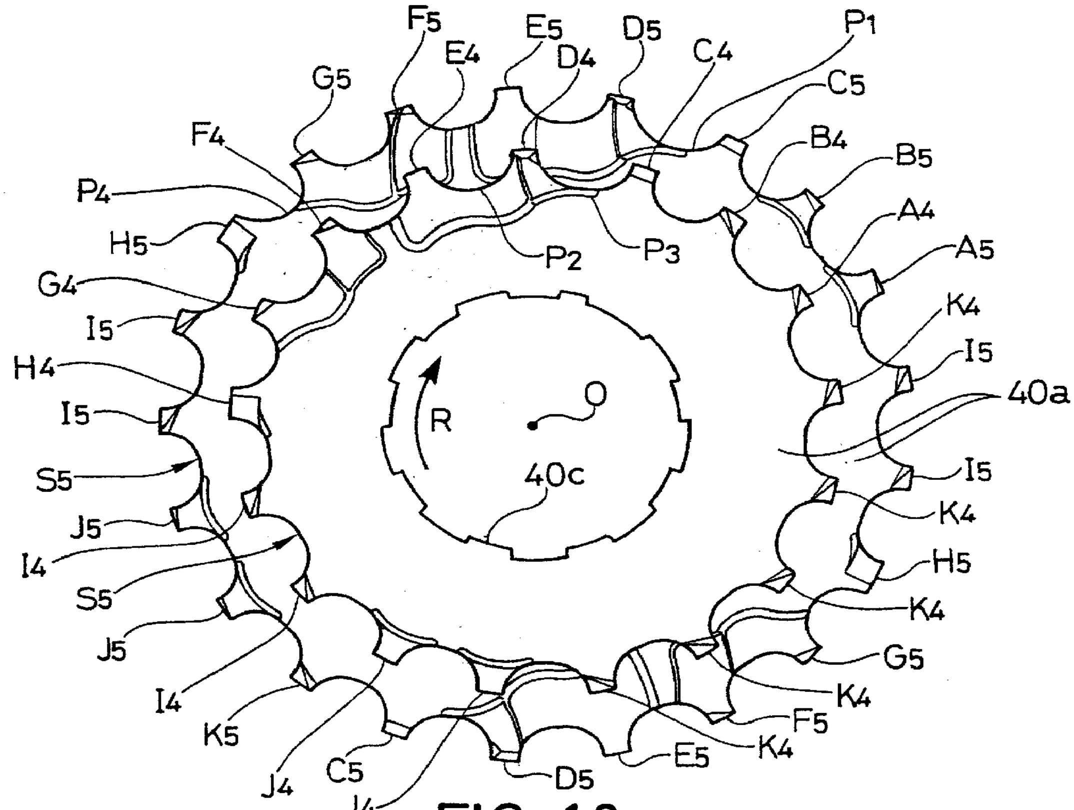
D5

FIG. 17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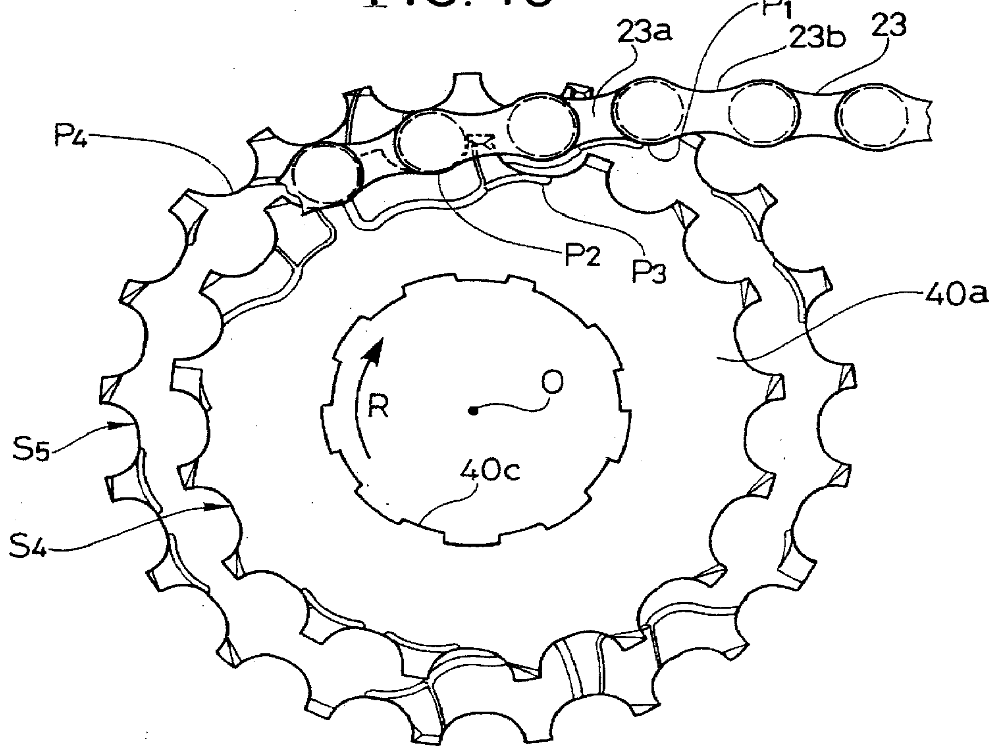
E5
D5
C4
P1
E4
D4
C5
G5
B4
B5
F4
P4
H5
P2
P3
A4
A5
G4
K4
I5
I5
H4
O
40a
I5
R
S5
I5
40c
J5
K4
I4
S5
H5
K4
J5
G5
I4
K4
K5
F5
K4
E5
C5
D5
J4
J4
FIG. 18


P1
23a
23b
23
P4
P2
P3
40a
O
R
S5
40c
S4
FIG. 19

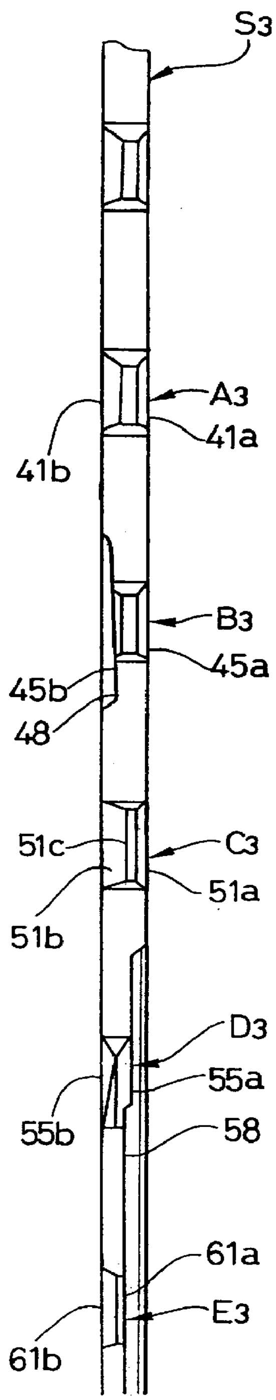


FIG. 20

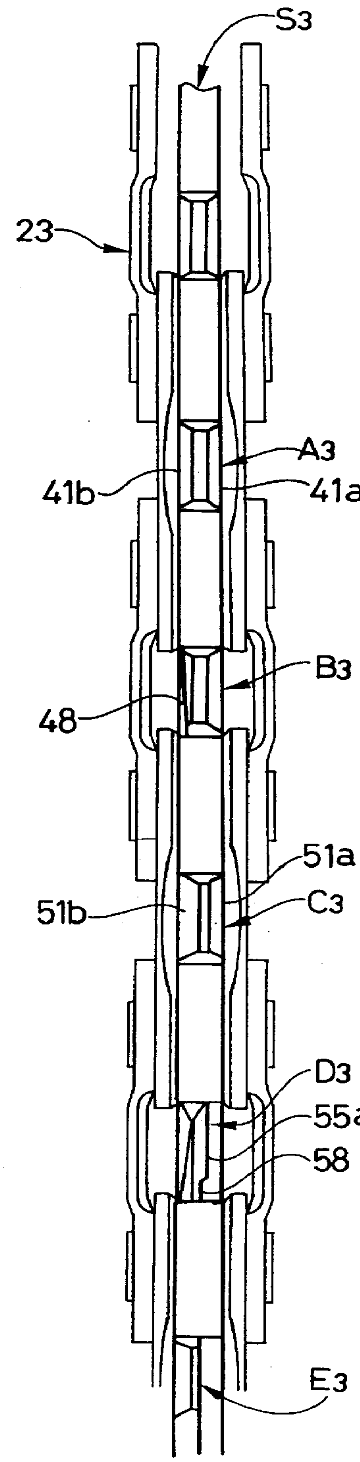


FIG. 21

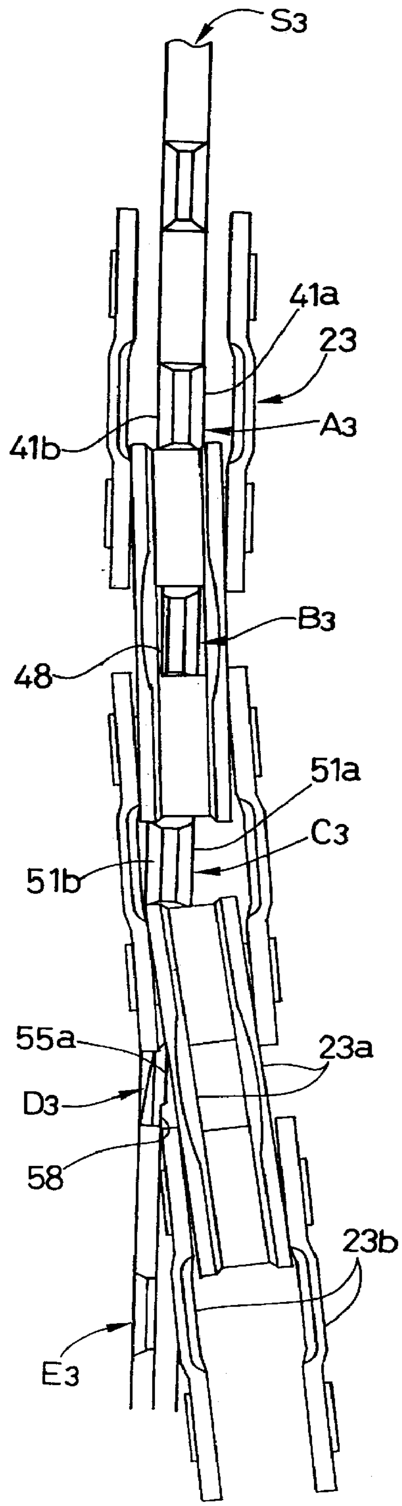


FIG. 22

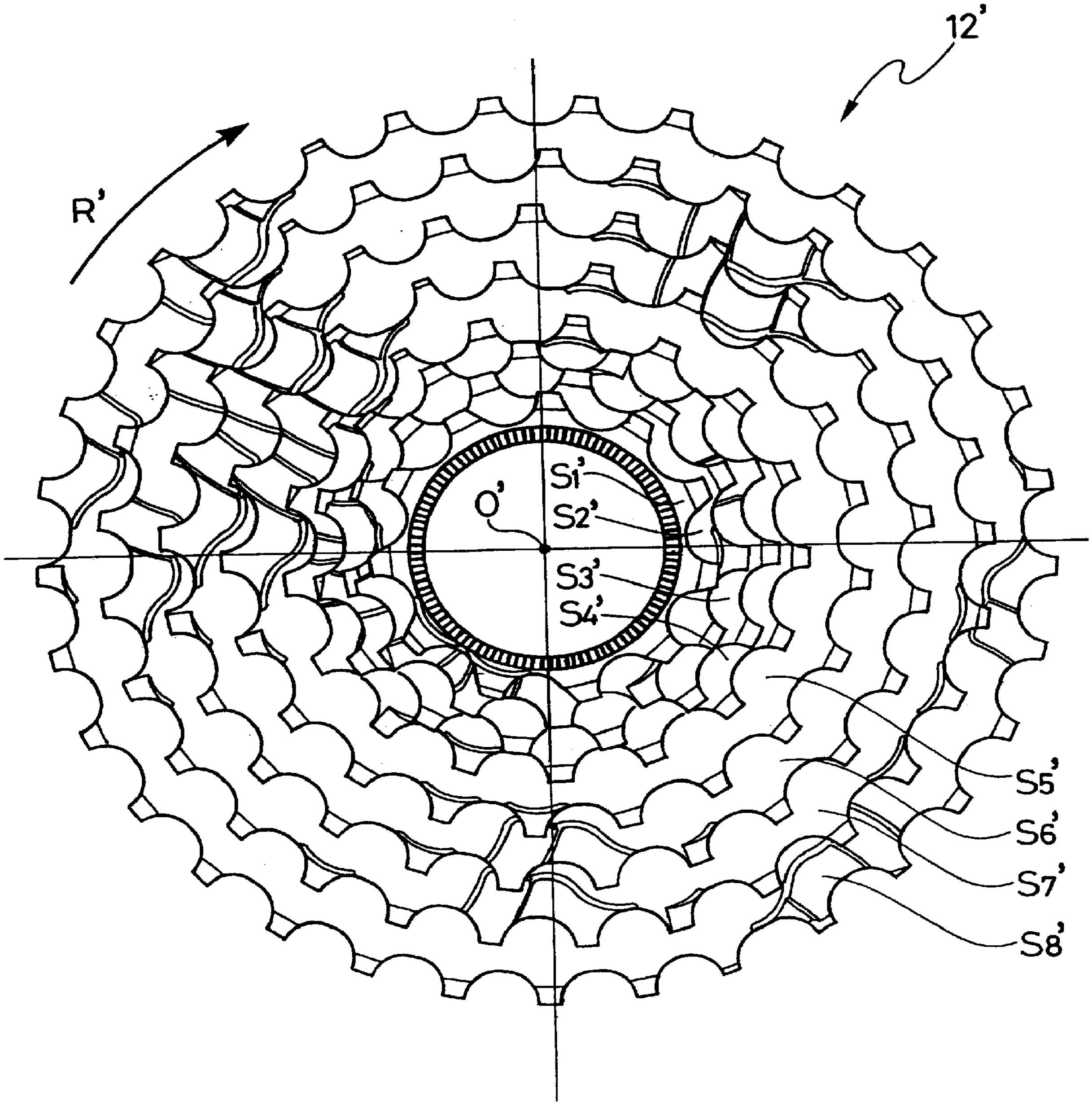


FIG. 23

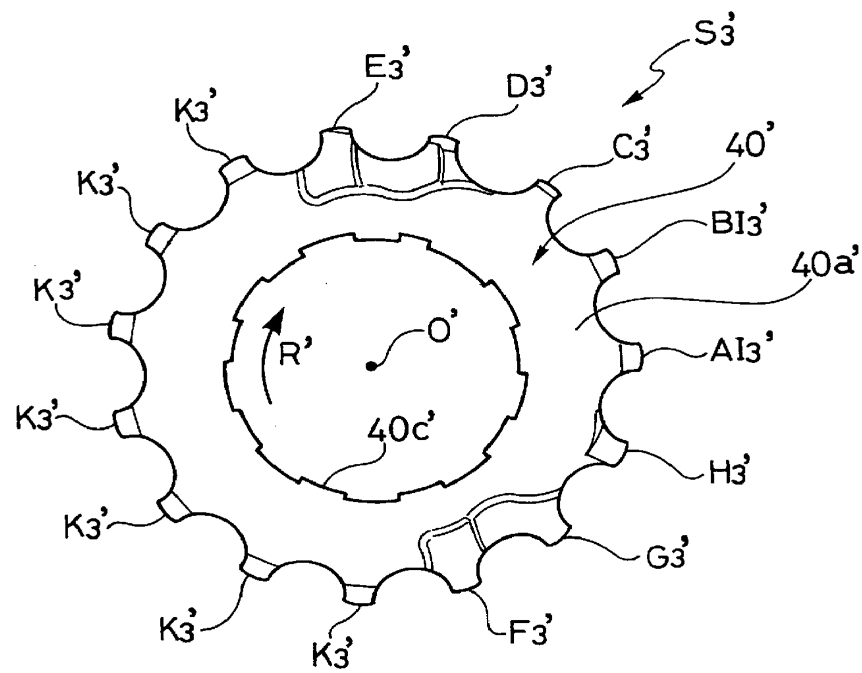

S3'
E3'
D3'
K3'
C3'
40'
K3'
BI3'
40a'
K3'
O'
R'
AI3'
K3'
40c'
H3'
K3'
G3'
K3'
F3'
K3'

FIG. 24

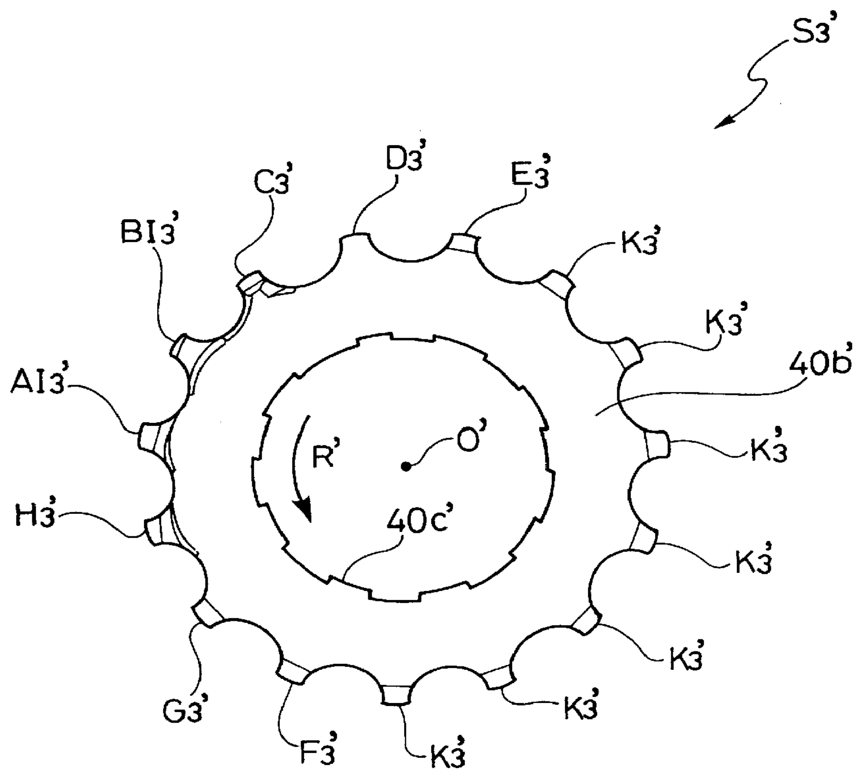

S3'
D3'
E3'
C3'
BI3'
K3'
K3'
40b'
AI3'
O'
K3'
R'
H3'
40c'
K3'
K3'
G3'
K3'
F3'
K3'

FIG. 25

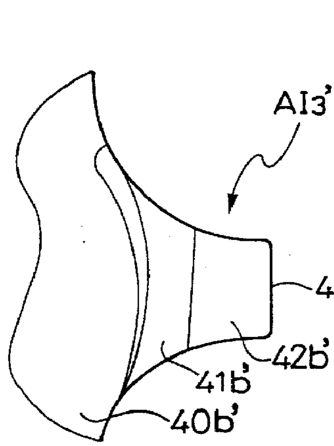


FIG. 26A

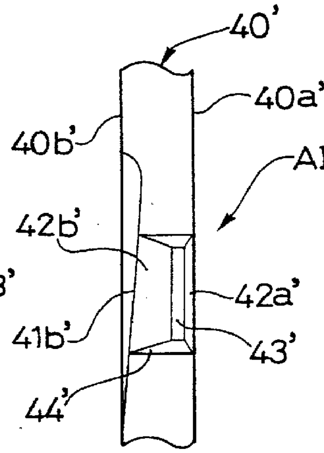


FIG. 26B

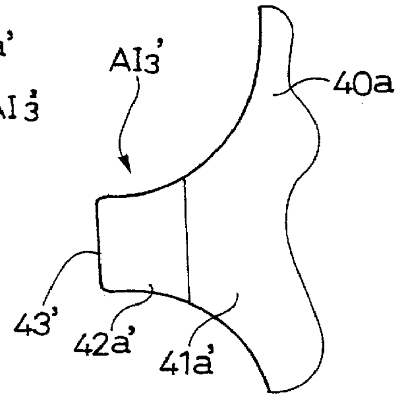


FIG. 26C

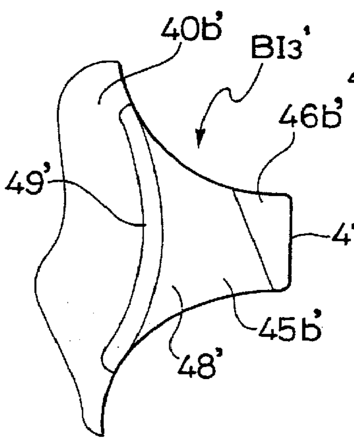


FIG. 27A

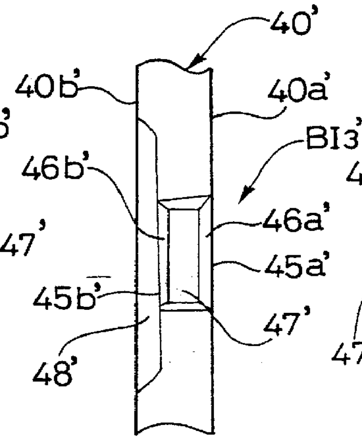


FIG. 27B

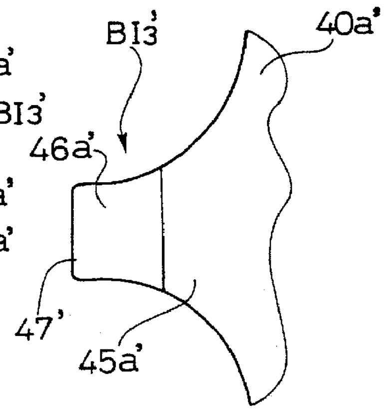


FIG. 27C

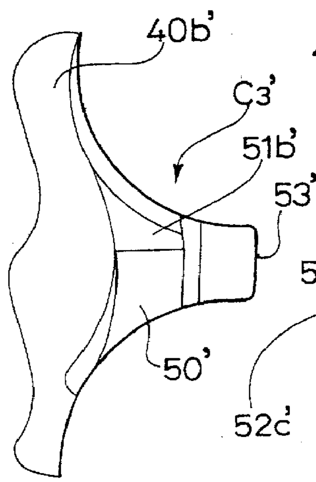


FIG. 28A

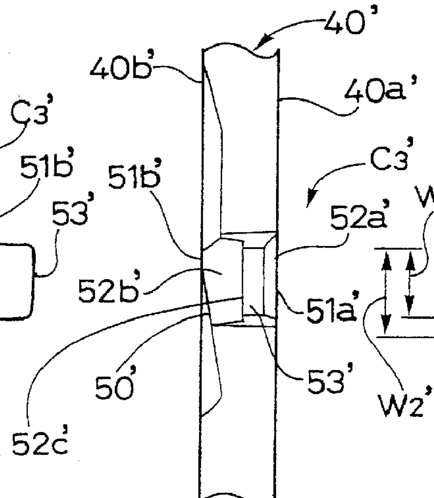


FIG. 28B

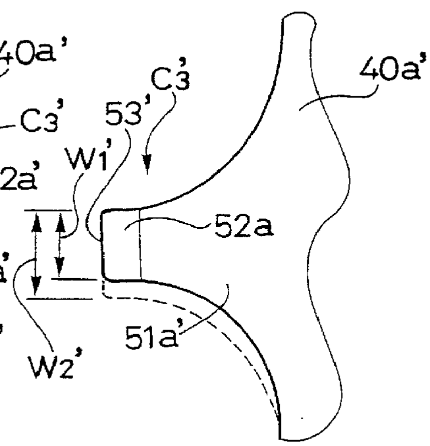


FIG. 28C

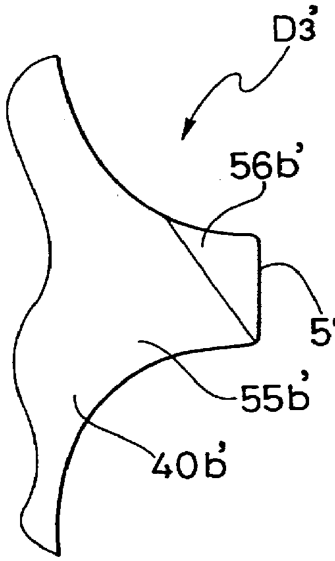


FIG. 29A

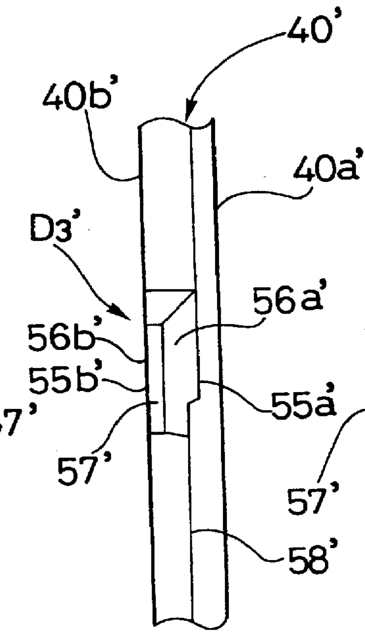


FIG. 29B

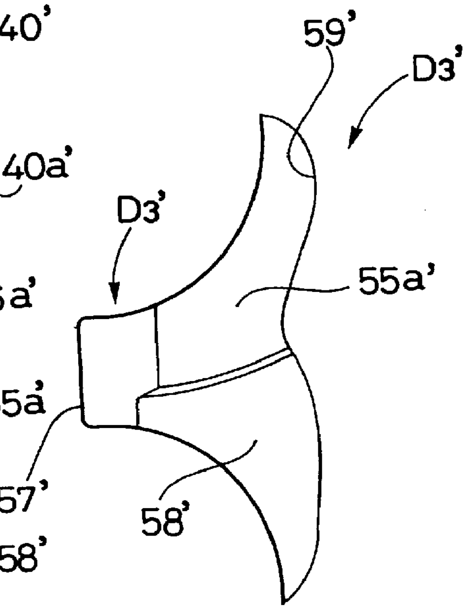


FIG. 29C

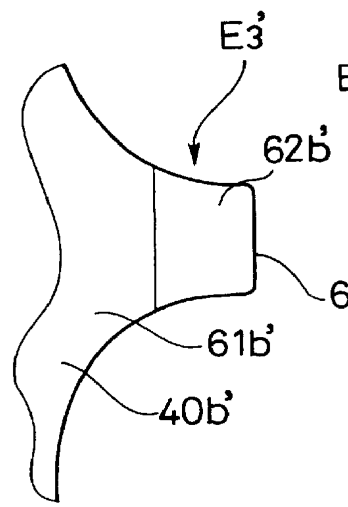


FIG. 30A

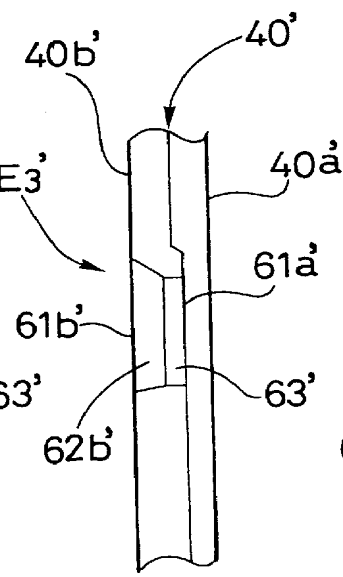


FIG. 30B

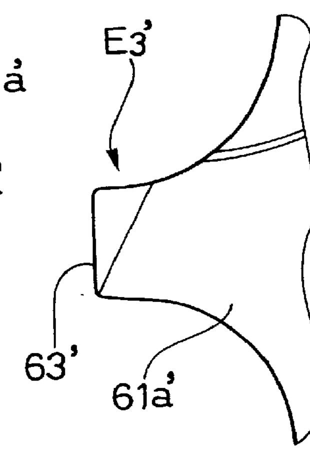
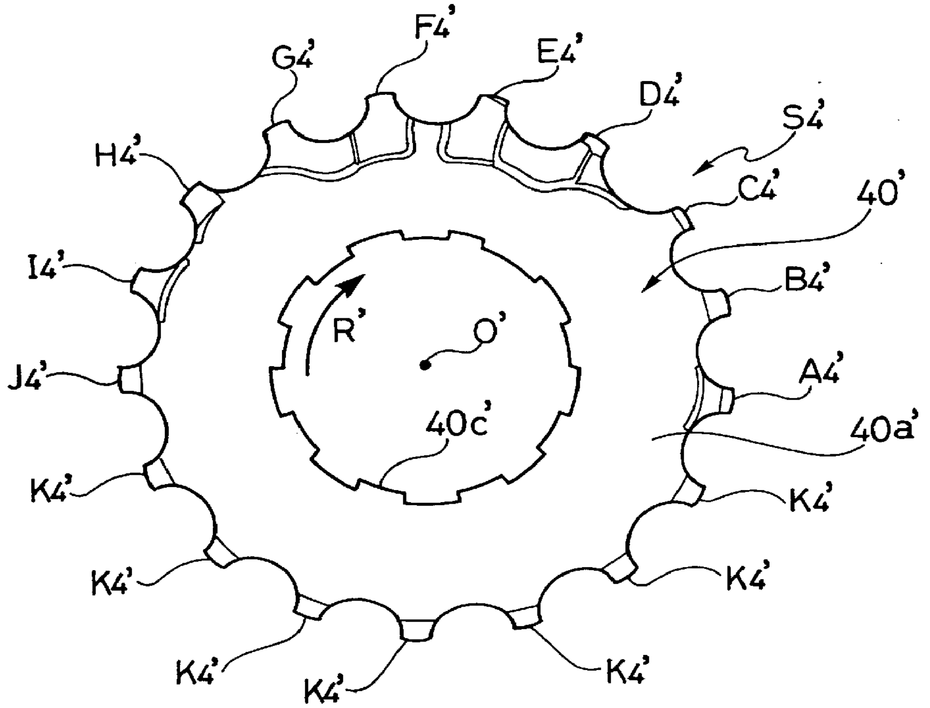
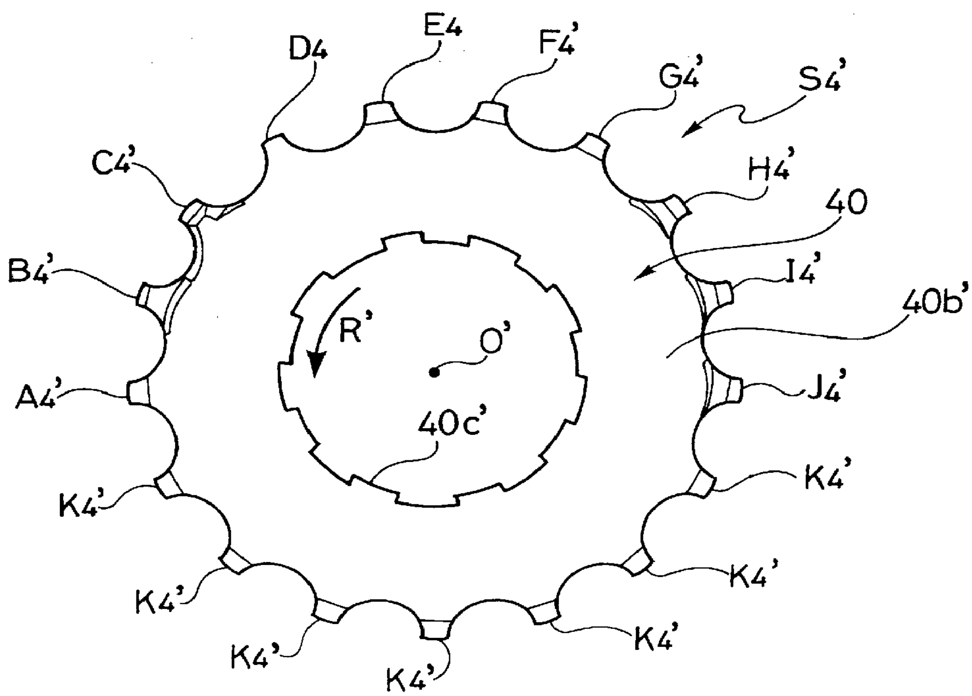


FIG. 30C



F4'
G4'
E4'
D4'
S4'
H4'
C4'
40'
I4'
B4'
R'
O'
J4'
A4'
40c'
40a'
K4'
K4'
K4'
K4'
K4'
K4'
K4'
K4'

FIG. 31



E4
D4
F4'
G4'
S4'
C4'
H4'
40
B4'
I4'
40b'
R'
O'
A4'
J4'
40c'
K4'
K4'
K4'
K4'
K4'
K4'
K4'

FIG. 32

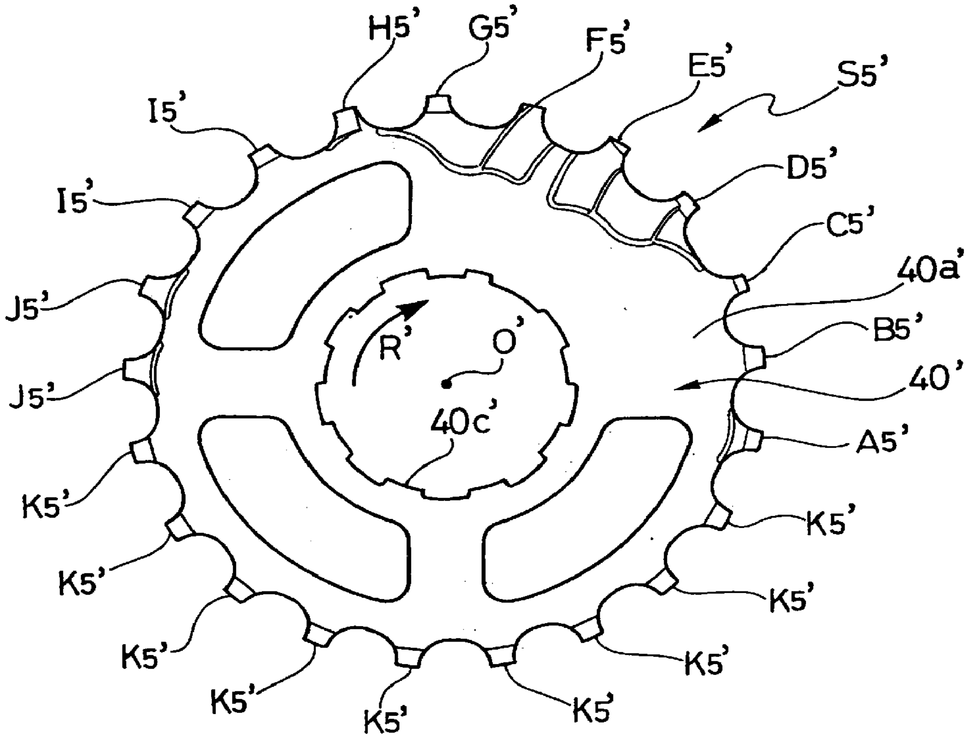
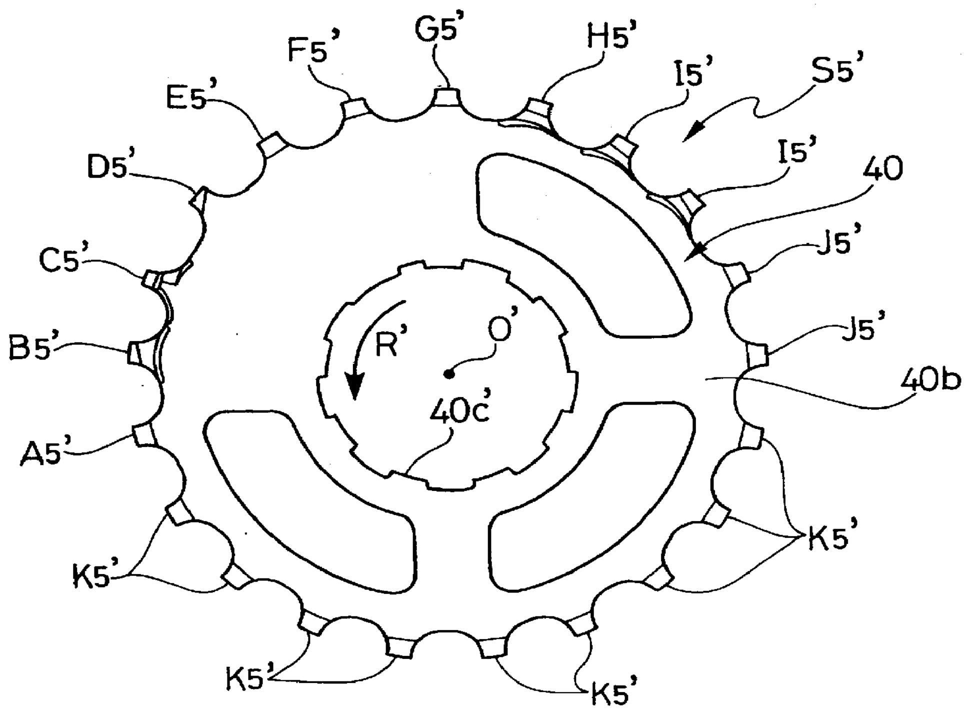

H5'
G5'
F5'
E5'
S5'
I5'
D5'
I5'
C5'
40a'
J5'
B5'
R'
O'
40'
J5'
40c'
A5'
K5'
K5'
K5'
K5'
K5'
K5'
K5'
K5'
K5'
K5'

FIG. 33


G5'
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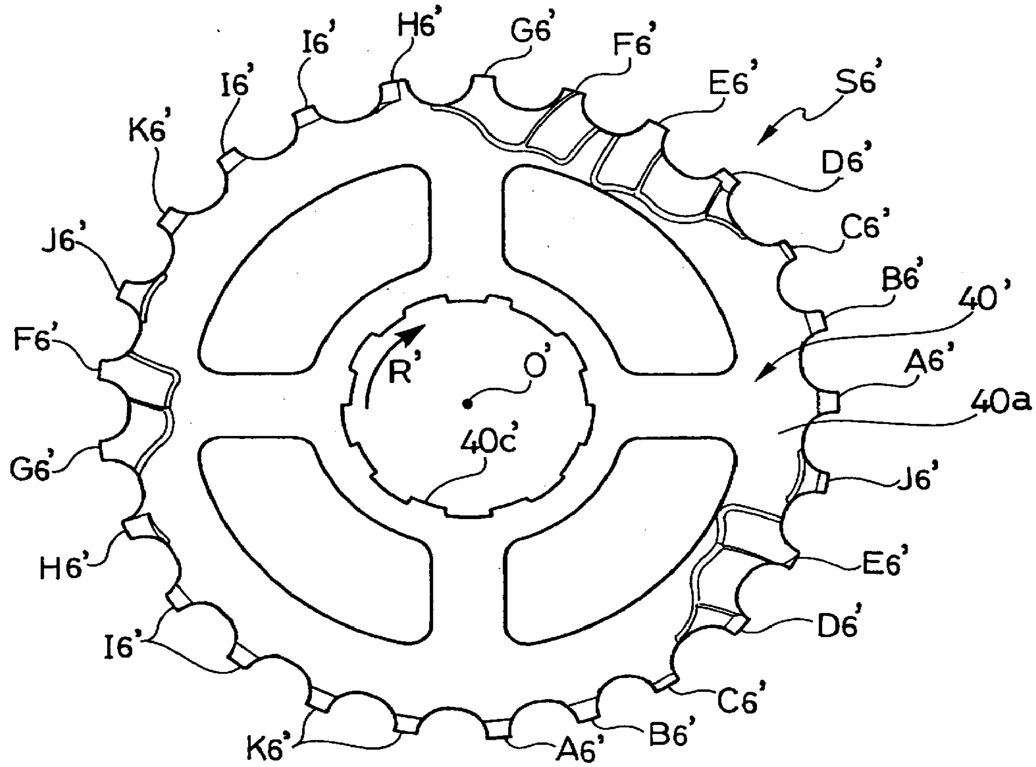
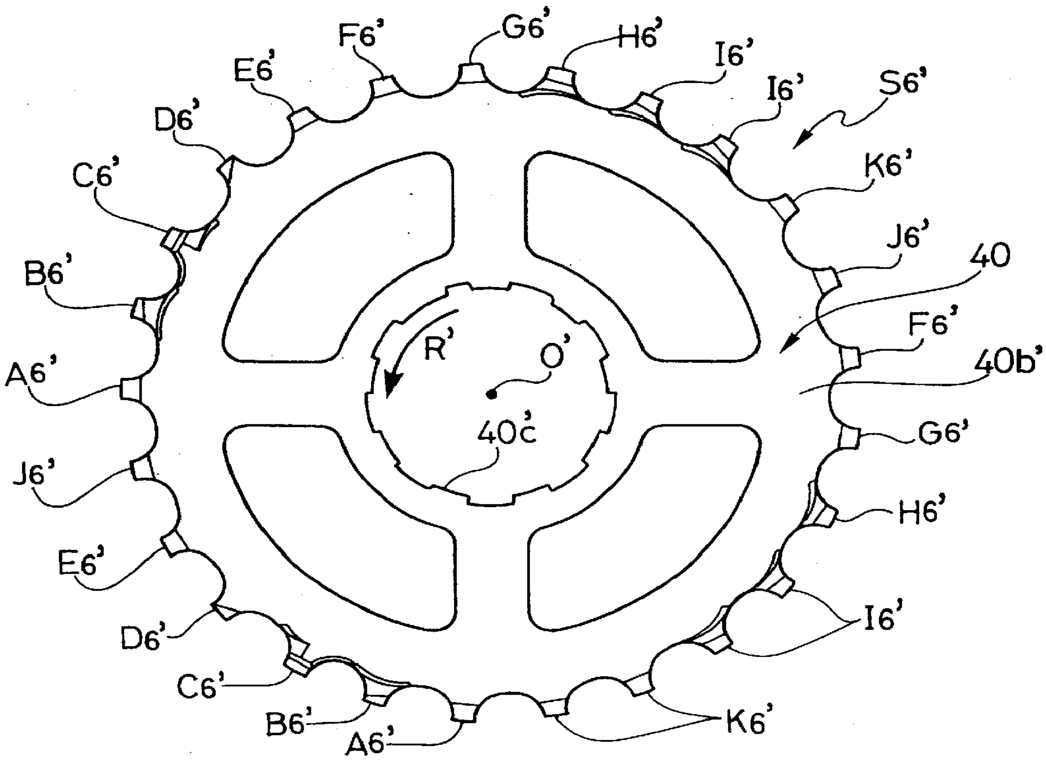
H5'
I5'
S5'
E5'
I5'
D5'
40
J5'
C5'
J5'
R'
O'
B5'
40b'
40c'
A5'
K5'
K5'
K5'
K5'

FIG. 34



H6'
G6'
F6'
E6'
S6'
I6'
I6'
K6'
D6'
C6'
J6'
B6'
40'
F6'
A6'
R'
O'
40a
G6'
40c'
J6'
E6'
H6'
D6'
I6'
C6'
K6'
A6'
B6'

FIG. 35



F6'
G6'
H6'
E6'
I6'
I6'
S6'
D6'
K6'
C6'
J6'
40
B6'
F6'
R'
O'
40b'
A6'
40c'
G6'
J6'
H6'
E6'
I6'
D6'
C6'
K6'
B6'
A6'

FIG. 36

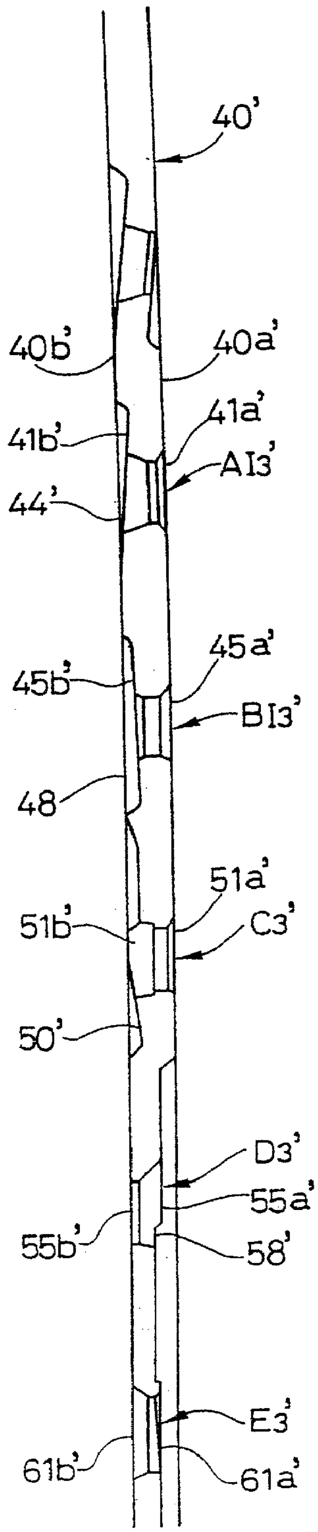


FIG. 37

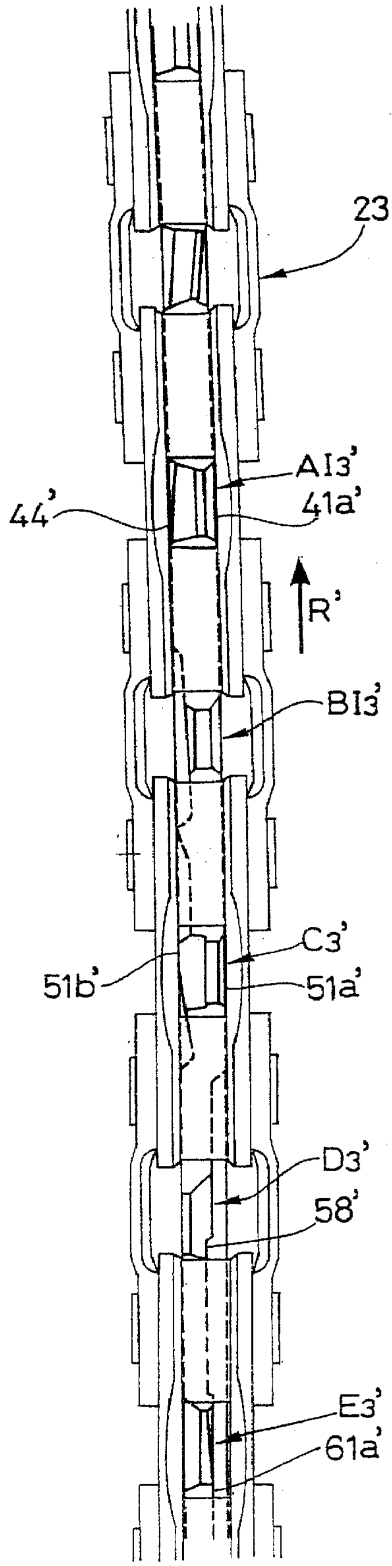


FIG. 38

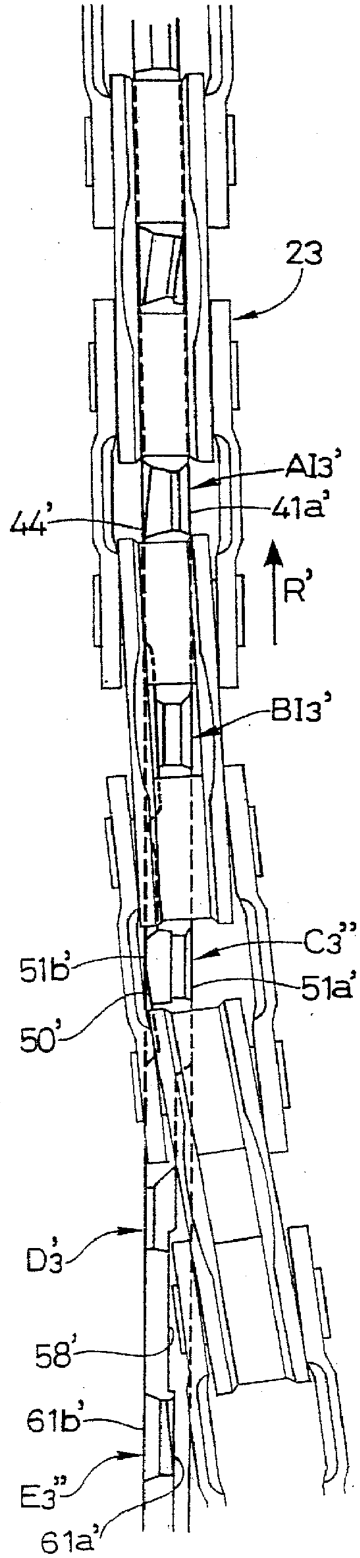
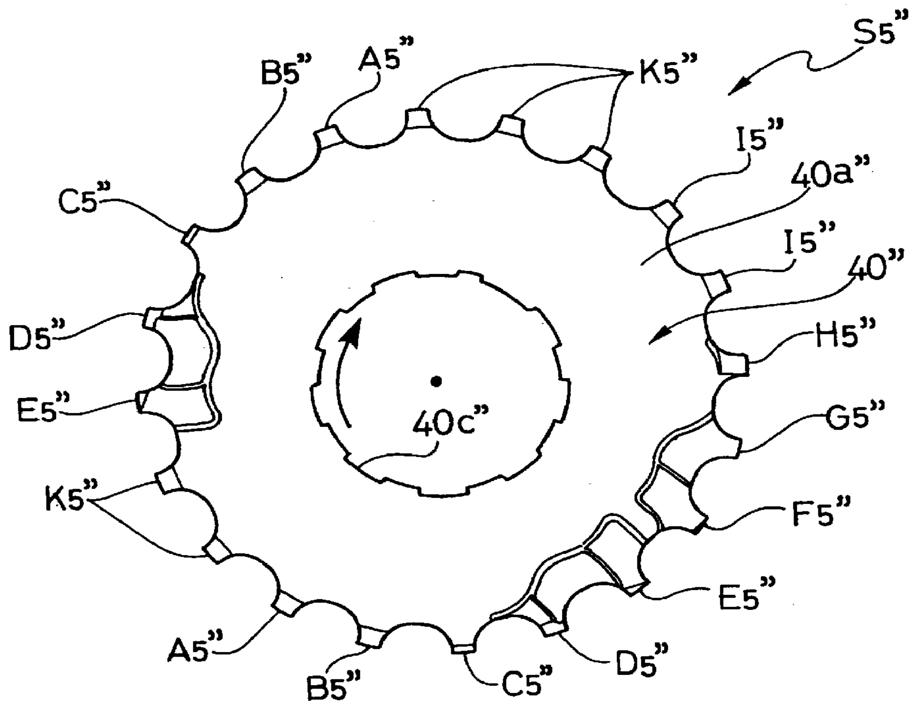
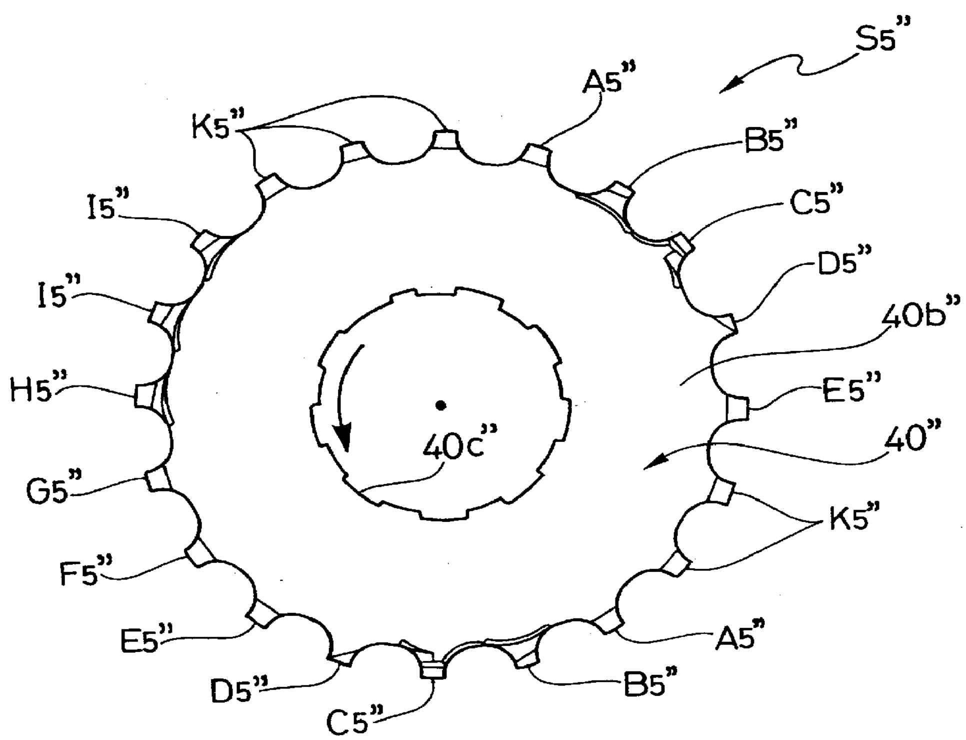


FIG. 39



S5"
B5"
A5"
K5"
I5"
40a"
C5"
I5"
40"
D5"
H5"
40c"
E5"
G5"
K5"
F5"
E5"
A5"
D5"
B5"
C5"

FIG. 40



S5"
A5"
K5"
B5"
C5"
I5"
D5"
I5"
40b"
H5"
E5"
40c"
40"
G5"
K5"
F5"
E5"
A5"
D5"
B5"
C5"

FIG. 41

BICYCLE SPROCKET

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to a multistage sprocket assembly for a bicycle. More specifically, the present invention relates to a sprocket assembly having at least one larger diameter sprocket and at least one smaller diameter sprocket with the teeth of at least the one larger diameter sprocket being dimensioned to allow for smoother shifting of the bicycle chain between the smaller sprocket and the larger sprocket.

2. Background Information

Bicycling is becoming an increasingly more popular form of recreation as well as a means of transportation. Moreover, bicycling has also become a very popular competitive sport for both amateurs and professionals. Whether the bicycle is used for recreation, transportation or competition, the bicycle industry is constantly improving the various components of the bicycle. The drive train of the bicycle has been redesigned over the past years. Specifically, manufacturers of bicycle components have been continually improving shifting performance of the various shifting components such as the shifter, the shift cable, the derailleur, the chain and the sprocket.

One particular component of the drive train that has been extensively redesigned is the sprocket assembly for the bicycle. More specifically, the bicycle sprocket assembly has been improved to provide smoother shifting.

Conventionally, a multistage sprocket assembly includes a smaller diameter sprocket and a larger diameter sprocket assembled such that: (1) the center point between a pair of adjacent teeth at the larger diameter sprocket and the center point between a pair of adjacent teeth at the smaller diameter sprocket are positioned on the tangent extending along the chain path; (2) a distance between the aforesaid center points is an integer multiple of the chain pitch; and (3) a first tooth of the larger diameter sprocket positioned behind the center point between the adjacent teeth at the larger diameter sprocket in the rotation direction for driving the bicycle is made to be easily engageable with the driving chain, thereby improving the speed change efficiency when the driving chain is shifted from the smaller diameter sprocket to the larger diameter sprocket.

The drive chain is a continuous loop that has a plurality of inner link plates and a plurality of outer link plates that are pivotally connected to each other by articulation pins and rollers. The space between the opposite surfaces of each pair of inner link plates is smaller than that between the opposite surfaces of each pair of outer link plates. In other words, each pair of the outer link plates is positioned outside the inner link plates and forms a space larger in width, while each pair of the inner link plates is positioned inside the outer link plates and form a space smaller in width.

The driving chain constructed as described above is biased by a derailleur toward either a larger diameter sprocket or a smaller diameter sprocket so as to be shifted thereto. Specifically, during a chain shifting process, the chain is shifted from one sprocket to the next adjacent sprocket by the rear derailleur moving the chain in an axial direction relative to the axis of rotation of the sprockets. By modifying the teeth of the large sprocket, the chain can execute smooth down shifting or up shifting motions. An up shift occurs when the chain is moved from a large sprocket to the next smaller sprocket. A down shift occurs when the chain is shifted from a small sprocket to the next larger sprocket.

Basically, when the sprocket assembly is rotated in a driving direction, the inner and outer link plates engage the teeth of one of the sprockets. In the case of a sprocket with an even number of teeth, the inner and outer link plates will always engage the same teeth. In the case of a sprocket with an odd number of teeth, the inner and outer link plates will alternately engage different teeth with each rotation of the sprocket assembly. Therefore, the teeth of the sprockets will alternately engage both the inner and outer link plates. The teeth of a sprocket with an odd number of teeth are typically designed to accommodate shifting with either the inner or outer link plates engaging the up shift teeth. Thus, the teeth of the sprocket must have one shift path for the inner link plates and another shift path for the outer link plates. If the chain is shifted on the wrong shift path, the rider will most like experience pedaling shock.

One example of an improved sprocket assembly is disclosed in U.S. Pat. No. 4,889,521 to Nagano. While the sprocket assembly disclosed in the Nagano patent operates very well in shifting from a smaller sprocket to a larger sprocket, no provision has been made for shifting from a large sprocket to a small sprocket. Moreover, Shimano introduced the Interactive Glide (IG) sprocket with the basic design of Shimano's HyperGlide (HG) sprocket plus uses new ramps and teeth configurations to control up shifts.

One example of a sprocket incorporating up shifting and downshifting paths is disclosed in U.S. Pat. No. 6,045,472 to Sung et al. The Sung et al. patent shows a sprocket designed to have two up shifting paths adjacent to each other. The Interactive Glide (IG) sprocket also has two up shift paths because of a combination problem of a sprocket with an even number of teeth and the outer link plates of the chain. In order to solve this problem, two up shifting paths were arranged adjacent so that one of the up shifting paths contributed for up shifting depending on the combination of the inner and outer links of the chain contacting the teeth of the sprocket.

More specifically, referring to FIG. **3** of the Sung et al. patent, when the outer link plate of the chain meshes with tooth **13**, the inner link plate of the chain is guided by **4**B. However, when the outer link plate of the chain meshes with tooth **14**, the inner link plate of the chain is guided by **4**C. Accordingly, design of **4**B and **4**C are different. The radial position of **4**C is higher than **4**B to take up slack of the chain from the second up shift escape point to a second up shift engagement point. Consequently, up shifting performance in the first up shift path and the adjacent second up shift path is different. One up shift path is superior to the other up shift path and such superior up shifting is so smooth that pedaling shock can be prevented. However, the other up-shift path is not so smooth and pedaling shock can occur.

In the course of up shifting the chain from the large sprocket to the small sprocket, the chain may ride on a tooth crest of either the small or large sprocket thus interfering with the chain shift without proper phase arrangement between the teeth of the large and small sprockets. If this happens, the rider will most like experience pedaling shock.

In view of the above, there exists a need for an improved sprocket assembly assuring smooth and reliable chain shift action from the large sprocket to the small sprocket. This invention addresses this need in the prior art as well as other needs, which will become apparent to those skilled in the art from this disclosure.

SUMMARY OF THE INVENTION

One object of the present invention is to provide a sprocket that is designed to provide a superior up shifting

path by modifying the sprocket teeth to assure smooth and reliable chain shift action from the large sprocket to the small sprocket.

The rider can enjoy smooth up shifting without pedal shock during up shifting with a derailleur. This improved multiple sprocket assembly has special advantages when used with motorized automatic shifting mechanisms.

One object of the present invention is to provide a large sprocket that provides a smooth up shifting action between a large sprocket to a small sprocket.

Another object of the present invention is to provide a sprocket assembly with at least one large sprocket and at least one small sprocket for shifting a chain from the large sprocket to the small sprocket relatively easily and reliably even under a heavy drive load.

The foregoing objects of the present invention can be attained by providing a large sprocket basically having a sprocket body with a first axial side and a second axial side, and a plurality of circumferentially spaced teeth extending radially and outwardly from an outer periphery of the sprocket body. The teeth of the sprocket include a plurality of up shift teeth. The up shift teeth has at least a first up shift tooth, a second up shift tooth located adjacent the first up shift tooth and a third up shift tooth located adjacent the second up shift tooth. The first, second and third up shift teeth are dimensioned to maintain alignment of a bicycle chain to prevent an up shift of the chain when an outer link plate of the bicycle chain meshes with the second up shift tooth, and to permit an up shift the bicycle chain when an inner link plate meshes with the second up shift tooth along a first up shift path.

These and other objects, features, aspects and advantages of the present invention will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses a preferred embodiment of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the attached drawings which form a part of this original disclosure:

FIG. **1**A is a side elevational view of a bicycle having a rear wheel with a sprocket assembly in accordance with the present invention;

FIG. **1**B is an enlarged partial, side elevational view of the handlebar and shift control unit of the bicycle illustrated in FIG. **1** showing manual up shift and down shift controls;

FIG. **2** is a rear diagrammatic elevational view of the seven-stage sprocket assembly according to the present invention;

FIG. **3** is a side elevational view of the seven-stage sprocket assembly in accordance with the present invention;

FIG. **4** is an enlarged partial top plan view of a portion of the chain that is used with the sprocket assembly illustrated in FIG. **3** in accordance with the present invention;

FIG. **5** is a small sprocket side elevational view of the fifteen teeth sprocket for the sprocket assembly illustrated in FIG. **3**;

FIG. **6** is a large sprocket side elevational view of the fifteen teeth sprocket illustrated in FIG. **5** for the sprocket assembly illustrated in FIG. **3**;

FIG. **7**A is a partial, large sprocket side elevational view of the first up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **7**B is a partial, overhead plan view of the first up shift tooth illustrated in FIG. **7**A for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **7**C is a partial, small side sprocket elevational view of the first up shift tooth illustrated in FIGS. **7**A and **7**B for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **8**A is a partial, large sprocket side elevational view of the second up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **8**B is a partial, overhead plan view of the second up shift tooth illustrated in FIG. **8**A for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **8**C is a partial, small sprocket side elevational view of the second up shift tooth illustrated in FIGS. **8**A and **8**B for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **9**A is a partial, large sprocket side elevational view of the third up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **9**B is a partial, overhead plan view of the third up shift tooth illustrated in FIG. **9**A for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **9**C is a partial, small sprocket side elevational view of the third up shift tooth illustrated in FIGS. **9**A and **9**B for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **10**A is a partial, large sprocket side elevational view of the fourth up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **10**B is a partial, overhead plan view of the fourth up shift tooth illustrated in FIG. **10**A for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **10**C is a partial, small sprocket side elevational view of the fourth up shift tooth illustrated in FIGS. **10**A and **10**B for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **11**A is a partial, large sprocket side elevational view of the fifth up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **11**B is a partial, overhead plan view of the fifth up shift tooth illustrated in FIG. **11**A for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **11**C is a partial, small sprocket side elevational view of the fifth up shift tooth illustrated in FIGS. **11**A and **11**B for the fifteen teeth sprocket illustrated in FIGS. **5** and **6**;

FIG. **12** is a small sprocket side elevational view of the seventeen teeth sprocket for the sprocket assembly illustrated in FIG. **3**;

FIG. **13** is a large sprocket side elevational view of the seventeen teeth sprocket illustrated in FIG. **12** for the sprocket assembly illustrated in FIG. **3**;

FIG. **14** is a small sprocket side perspective view of the seventeen teeth sprocket illustrated in FIGS. **12** and **13** for the sprocket assembly illustrated in FIG. **3**;

FIG. **15** is a large sprocket side perspective view of the seventeen teeth sprocket illustrated in FIGS. **12–14** for the sprocket assembly illustrated in FIG. **3**;

FIG. **16** is a small sprocket side elevational view of the twenty-one teeth sprocket for the sprocket assembly illustrated in FIG. **3**;

FIG. **17** is a large sprocket side elevational view of the twenty-one teeth sprocket illustrated in FIG. **16** for the sprocket assembly illustrated in FIG. **3**;

FIG. **18** is a small sprocket side elevational view of the seventeen teeth sprocket and the twenty-one teeth sprocket coupled together;

FIG. **19** is a small sprocket side elevational view of the seventeen teeth sprocket and the twenty-one teeth sprocket with a chain being up shifted from the twenty-one teeth sprocket to the seventeen teeth sprocket;

FIG. **20** is a partial edge elevational view of the up shift teeth of the fifteen teeth sprocket illustrated in FIGS. **5** and **6** for the sprocket assembly illustrated in FIG. **3**;

FIG. **21** is a partial edge elevational view of the fifteen teeth sprocket illustrated in FIGS. **5** and **6** for the sprocket assembly illustrated in FIG. **3** with the first and third up shift teeth engaging inner link plates to prevent the chain from up shifting to the thirteen teeth sprocket of the sprocket assembly illustrated in FIG. **3**;

FIG. **22** is a partial edge elevational view of the fifteen teeth sprocket illustrated in FIGS. **5** and **6** for the sprocket assembly illustrated in FIG. **3** with the first and third up shift teeth engaging outer link plates to permit up shifting of the chain to the thirteen teeth sprocket of the sprocket assembly illustrated in FIG. **3**;

FIG. **23** is a side elevational view of an eight-stage sprocket assembly in accordance with a second embodiment of the present invention;

FIG. **24** is a small sprocket side elevational view of the fifteen teeth sprocket of the sprocket assembly illustrated in FIG. **23**;

FIG. **25** is a large sprocket side elevational view of the fifteen teeth sprocket of the sprocket assembly illustrated in FIGS. **23** and **24**;

FIG. **26**A is a partial, large sprocket side elevational view of the integrated first up shift/second down shift tooth of the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **26**B is a partial, overhead plan view of the integrated first up shift/second down shift tooth illustrated in FIG. **26**A for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **26**C is a partial, small sprocket side elevational view of the integrated first up shift/second down shift tooth illustrated in FIGS. **26**A and **26**B for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **27**A is a partial, large sprocket side elevational view of the integrated second up shift/third down shift tooth of the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **27**B is a partial, overhead plan view of the integrated second up shift/third down shift tooth illustrated in FIG. **27**A for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **27**C is a partial, small sprocket side elevational view of the integrated second up shift/third down shift tooth illustrated in FIGS. **27**A and **27**B for the **15** fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **28**A is a partial, large sprocket side elevational view of the third up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **28**B is a partial, overhead plan view of the third up shift tooth illustrated in FIG. **28**A for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **28**C is a partial, small sprocket side elevational view of the third up shift tooth illustrated in FIGS. **28**A and **28**B for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **29**A is a partial, large sprocket side elevational view of the fourth up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **29**B is a partial, overhead plan view of the fourth up shift tooth illustrated in FIG. **29**A for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **29**C is a partial, small sprocket side elevational view of the fourth up shift tooth illustrated in FIGS. **29**A and **29**B for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **30**A is a partial, large sprocket side elevational view of the fifth up shift tooth of the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **30**B is a partial, overhead plan view of the fifth up shift tooth illustrated in FIG. **30**A for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **30**C is a partial, small sprocket side elevational view of the fifth up shift tooth illustrated in FIGS. **30**A and **30**B for the fifteen teeth sprocket illustrated in FIGS. **24** and **25**;

FIG. **31** is a small sprocket side elevational view of the seventeen teeth sprocket for the sprocket assembly illustrated in FIG. **23**;

FIG. **32** is a large sprocket side elevational view of the seventeen teeth sprocket illustrated in FIG. **31** for the sprocket assembly illustrated in FIG. **23**;

FIG. **33** is a small sprocket side elevational view of the twenty-one teeth sprocket for the sprocket assembly illustrated in FIG. **23**;

FIG. **34** is a large sprocket side elevational view of the twenty-one teeth sprocket illustrated in FIG. **33** for the sprocket assembly illustrated in FIG. **23**;

FIG. **35** is a small sprocket side elevational view of the twenty-five teeth sprocket for the sprocket assembly illustrated in FIG. **23**;

FIG. **36** is a large sprocket side elevational view of the twenty-five teeth sprocket illustrated in FIG. **35** for the sprocket assembly illustrated in FIG. **23**;

FIG. **37** is a partial edge elevational view of the up shift teeth of the fifteen teeth sprocket illustrated in FIGS. **24** and **25** for the sprocket assembly illustrated in FIG. **23**;

FIG. **38** is a partial edge elevational view of the fifteen teeth sprocket illustrated in FIGS. **24** and **25** for the sprocket assembly illustrated in FIG. **23** with the first and third up shift teeth engaging inner link plates to prevent the chain from up shifting to the thirteen teeth sprocket of the sprocket assembly illustrated in FIG. **23**;

FIG. **39** is a partial edge elevational view of the fifteen teeth sprocket illustrated in FIGS. **24** and **25** for the sprocket assembly illustrated in FIG. **23** with the first and third up shift teeth engaging outer link plates to permit up shifting of the chain to the thirteen teeth sprocket of the sprocket assembly illustrated in FIG. **23**;

FIG. **40** is a small sprocket side elevational view of an even numbered teeth sprocket in accordance with the present invention; and

FIG. **41** is a large sprocket side elevational view of the even numbered teeth sprocket illustrated in FIG. **40**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring initially to FIG. **1**A, a conventional bicycle **10** is illustrated with a rear bicycle hub **11** having a multi-stage sprocket assembly **12** in accordance with the present invention. The bicycle **10** basically has a frame **14** with front and rear wheels **15** and **16** rotatably coupled thereto. A front fork **17** is coupled between the frame **14** and the front wheel **15** in a conventional manner. Turning a handlebar **18**, which is fixedly coupled to the front fork **17**, turns the front wheel **15**. The rear wheel **16** is rotatably coupled to a rear portion of the frame **14**. The frame **14** also has a seat **19** adjustably coupled to frame **14** and a drive train **20** for propelling bicycle **10**.

The drive train **20** basically includes the rear multi-stage sprocket assembly **12** of the present invention, a pair of pedals **21**, a front multi-stage sprocket assembly **22** mounted to rotate with the pedals **21**, and a chain **23** extending between the rear multi-stage sprocket assembly **12** and the

front multi-stage sprocket assembly **22**. The drive train **20** is basically operated by an electronically controlled automatic shifting assembly. The electronically controlled automatic shifting assembly basically includes a shift control unit **25**, a junction box or connection unit **26**, a motorized front derailleur **27**, and a motorized rear derailleur or chain shifting device **28**. The shift control unit **25** includes a microcomputer formed on a printed circuit board that is powered by a battery unit. The microcomputer of shift control unit **25** includes a central processing unit (CPU), a random access memory component (RAM), a read only memory component (ROM), and an I/O interface. The shift control unit **25** is preferably automatic as discussed in more detail below. The various components of the microcomputer are well known in the bicycle field. Therefore, the components used in the microcomputer of the shift control unit **25** will not be discussed or illustrated in detail herein. Moreover, it will be apparent to those skilled in the art from this disclosure that the shift control unit **25** can include various electronic components, circuitry and mechanical components to carryout the present invention.

The shift control unit **25** also preferably includes manual down and up shift buttons or levers **25***a* and **25***b*, respectively, for manually operating the front and/or rear derailleurs **27** and **28**, as seen in FIG. **1**B. A protrusion **25***c* is arranged between buttons **25***a* and **25***b* to provide a reference point for the rider's thumb or finger relative to buttons **25***a* and **25***b*. The shift control unit **25** further includes at least one sensing/measuring device or component that provides information to its central processing unit. The sensing/measuring component generates predetermined operational commands. Thus, the sensing/measuring components are operatively coupled to central processing unit of the shift control unit **25** such that predetermined operational commands are received by the central processing unit (CPU).

The shift control unit **25** sends a signal to the front derailleur **27** and/or rear derailleur **28** via connection unit **26** for automatic shifting. The connection unit preferably includes a single power input for receiving signals from the shift control unit **25** and a pair of power outputs for sending signals to the front and/or rear derailleurs **27** and **28**. The power input operatively couples the shift control unit **25** to the connection unit **26**. Preferably, one power output operatively couples front derailleur **27** to connection unit **26** and the other power output operatively couples to rear derailleur **28** to connection unit **26**.

One type of sensing/measuring component that can be used to operate the shift control unit **25** is a speed sensing unit. The shift control unit **25**, and the connection unit **26** are operatively coupled to the speed sensing unit, which includes a sensor **29** and a magnet **30**. The sensor **29** is preferably a magnetically operable sensor that is mounted on the front fork **17** and senses the magnet **30** that is attached to one of the spokes of the front wheel **15**. Thus, speed information is sent to the battery operated electronic shift control unit **25**. The bicycle speed sensor **29** is coupled to the front fork **17** of bicycle **10**. This bicycle speed sensor **29** outputs a bicycle speed signal by detecting a magnet **30** mounted on the front wheel **15**. The sensor **29** has a front read switch or other component for detecting the magnet **30** rotating with the wheel **15**. Sensor **29** generates a pulse each time wheel **15** has turned a pre-described angle or rotation. As soon as sensor **29** generates the pulse or signal, a pulse signal transmission circuit sends this pulse signal to the central processing unit of the shift control unit **25** to determine whether the chain **23** should be up shifted or down shifted. Thus, the sensor **29** and the magnet **30** form a sensing device or measuring component of the shift control unit **25**. In other words, the sensor **29** detects the rotational velocity of the front wheel **15**.

The multiple sprocket assembly **12** of the present invention is especially useful when used in conjunction with the automatic shifting assembly that operates the motorized rear derailleur **28**. One example of an automatic shifting assembly that can be utilized with the present invention is disclosed in U.S. Pat. No. 6,073,061 to Kimura, which is assigned to Shimano Inc.

In such a device, when the bicycle speed exceeds a predetermined upper speed value, then the automatic shifting assembly actuates the rear derailleur **28** to move the chain **23** in an up shifting direction. When the bicycle speed becomes lower than a predetermined lower speed value, then the automatic shifting assembly actuates the rear derailleur **28** to move the chain **23** in a down shifting direction. When the automatic shifting assembly is set to manual shifting, the rider can anticipate when is the best time to shift the rear derailleur **28** so as to minimize sudden pedaling shock. However, when the automatic shifting assembly is in the automatic mode, the rider cannot predict when the shifting will occur. Therefore, the rider cannot prevent the rear derailleur **28** from shifting at a point when sudden pedaling shock is highly likely. However, using the multiple sprocket assembly **12** of the present invention, sudden pedaling shock is reduced or eliminated even when the automatic shifting assembly is in the automatic shifting mode.

Since the parts of the bicycle **10** and the drive train **20** are well known in the bicycle art, these parts of the bicycle **10** will not be discussed or illustrated in detail herein, except as they are modified in accordance with the present invention. Moreover, various conventional bicycle parts such as brakes, additional sprockets, etc., which are not illustrated and/or discussed in detail herein, can be used in conjunction with the present invention.

As used herein, the terms "forward, rearward, above, below, lateral and transverse" refer to those directions of a bicycle in its normal riding position, to which the sprocket assembly **12** is attached. Accordingly, these terms, as utilized to describe the sprocket assembly **12** in the claims, should be interpreted relative to bicycle **10** in its normal riding position.

FIRST EMBODIMENT

Referring now to FIGS. **2** and **3**, the sprocket assembly **12** will now be discussed in accordance with a first embodiment of the present invention. In this first embodiment, the sprocket assembly **12** is a seven stage sprocket assembly with sprockets S_1–S_7 being spaced from each other at a predetermined interval. The sprockets S_1–S_7 are fixedly mounted on a freewheel **11** (not shown) of the rear hub in a conventional manner such that the sprockets S_1–S_7 rotate together about the center hub axis O. The sprockets S_1–S_7 rotate together in a clockwise direction R as view in FIG. **3**.

It will be apparent to those skilled in the bicycle art from this disclosure that a sprocket assembly in accordance with the present invention can have fewer or more sprockets. In other words, the present invention can be any multi-stage sprocket assembly for a bicycle that uses a derailleur or the like, and which includes at least one large sprocket and at least one small sprocket.

The multistage sprocket assembly **12** is adapted to engage with the drive chain **23**, which is a conventional style bicycle chain as seen in FIG. **4**. The drive chain **23** is a continuous

loop that has a plurality of inner link plates **23***a* and a plurality of outer link plates **23***b* that are pivotally connected to each other by articulation pins and rollers. During a chain shifting process, the chain **23** is shifted from one sprocket to the next adjacent sprocket by the rear derailleur **28** moving the chain **23** in an axial direction relative to the axis of rotation of the sprockets S_1–S_7. By modifying the teeth of the large sprocket, the chain **23** can execute smooth down shifting or up shifting motions.

Referring now to FIG. **2**, the sprocket assembly **12** is diagrammatically illustrated to show the directions of an up shift and a down shift. Specifically, an up shift occurs when the chain **23** is moved from a large sprocket to the next smaller sprocket. A down shift occurs when the chain **23** is shifted from a small sprocket to the next larger sprocket.

Basically, when the sprocket assembly **12** is rotated in a clockwise direction R as viewed in FIG. **3**, the inner and outer link plates **23***a* and **23***b* engage the teeth of one of the sprockets. In the case of a sprocket with an even number of teeth, the inner and outer link plates **23***a* and **23***b* will always engage the same teeth. In the case of a sprocket with an odd number of teeth, the inner and outer link plates **23***a* and **23***b* will alternately engage different teeth with each rotation of the sprocket assembly **12**. Therefore, the teeth of the sprockets S_3, S_4 and S_5 (all having an odd number of teeth) will alternately engage both the inner and outer link plates **23***a* and **23***b*. The teeth of the sprockets S_3, S_4 and S_5 are especially designed such that an up shift operation only occurs when one of the inner link plates **23** engages a selected tooth of the sprocket, as discussed below.

In first embodiment, the multistage sprocket assembly **12** of the invention has a teeth configuration of **11**T-**13**T-**15**T-**17**T-**21**T-**27**T-**33**T for the sprockets S_1–S_7, respectively. Of course, it will be apparent to those skilled in the bicycle art from this disclosure that the sprockets S_1–S_7 can have other teeth configurations. The present invention is optimized for a sprocket having a total number of teeth equaling an odd number. Of course, it will be apparent to those skilled in the bicycle art that the sprockets of the present invention can be configured with a total number of teeth equaling an even number, as discussed below. The sprockets S_1–S_7 are preferably constructed of a suitable rigid material such as a metallic material.

The axial widths of the sprockets S_1–S_7 and the lateral spacing between the inner link plates **23***a* of the chain **23** are dimension to control the up shifting of the chain **23** as explained below. For example, the chain **23** has a lateral spacing between the inner link plates **23***a* of approximately 2.5 millimeters, while the sprockets S_1–S_7 preferably have an axial width of approximately 2.3 millimeters for the seven stage sprocket assembly **12**. For an eight stage sprocket assembly (i.e., sprocket assembly **12'** of the second embodiment), the axial width is preferably approximately 2.1 millimeters, as discussed in more detail.

For the sake of brevity, only the sprockets S_3, S_4 and S_5 will be discussed and/or illustrated in detail herein when discussing the first embodiment of bicycle sprocket assembly **12** in accordance with the present invention. Of course, it will be apparent to those skilled in the bicycle art that the principles of the present invention as discussed relative to sprockets S_3–S_5 can be applied to the other sprockets (i.e., S_1, S_2, S_6 and S_7) of the sprocket assembly **12**.

Referring now to FIGS. **5** and **6**, the sprocket S_3 basically has a sprocket body **40** and a plurality (fifteen) of circumferentially spaced teeth A_3–K_3 extending radially and outwardly from an outer periphery of the sprocket body **40**. The term "outer periphery of the sprocket body" as used herein lies on a circle that corresponds to the root diameter of teeth A_3–K_3. The sprocket body **40** has a first axial side or small sprocket side **40***a* that faces the next smaller sprocket S_2 and a second axial side or large sprocket side **40***b* that faces the next larger sprocket S_4. The center of the sprocket S_3 is provided with a splined bore **40***c* that is mounted on the freewheel **11** (not shown) of the rear hub in a conventional manner. For convenience sake, the teeth of the sprocket S_3 have been labeled alphabetically in a counterclockwise direction relative to the direction of rotation R of the sprocket S_3 with substantially identical teeth typically having the same reference character. The teeth of the sprockets S_4 and S_5 will use similar nomenclature for the teeth that are substantially identical to teeth of the sprocket S_3.

As explained below, selected teeth of sprocket S_3 are trimmed so that the chain **23** can be smoothly up shifted or down shifted to the adjacent sprockets S_2 and S_4. The consecutive teeth A_3–E_3 are up shift teeth that work together to control the up shifting of the chain **23** and form a first up shift path. The consecutive teeth F_3–I_3 are down shift teeth that work together to control the down shifting of the chain **23** and form a first down shift path. While the sprocket S_3 is illustrated with only one up shift path and only one down shift path, it will be apparent to those skilled in the bicycle art from this disclosure that the sprocket S_3 can be provided with two up shift paths and two down shift paths.

When the chain **23** is shifted from a first sprocket such as sprocket S_3 to the next smaller or larger sprocket such as sprocket S_2 or S_4, the center point of the last roller that engages with the first sprocket is referred to as the escape point, and the center of the first roller that engages with the receiving sprocket is referred to as the engagement point. The chain links between the escape point and the engagement point form the up shift path or the down shift path of the chain during a chain shifting process.

Referring to FIGS. **18** and **19**, the shifting motion of the chain **23** will now be discussed in more detail. In an up shifting operation, the chain **23** is shifted from the larger sprocket S_5 to the smaller sprocket S_4. In this up shifting process, the larger sprocket S_5 is considered the original sprocket, and thus, the smaller sprocket S_4 is considered the receiving sprocket. The larger sprocket S_5 has the up shifting escape point P_1, while the smaller sprocket S_4 has the up shifting engagement point P_2 In the down shifting process, the smaller sprocket S_4 is considered the original sprocket, and thus, the larger sprocket S_5 is considered the receiving sprocket. The smaller sprocket S_4 has the down shifting escape point P_3, and the larger sprocket S_5 has the down shifting engagement point P_4.

The angle formed by the escape point and the engagement point to the center of the sprocket assembly **12** is defined as the phase angle between the larger sprocket S_5 and the smaller sprocket S_4. In the down shifting motion this phase angle is referred to as the down shifting phase angle, while in the up shifting motion this phase angle is referred to as the up shifting phase angle.

The down shift teeth F_3–I_3 are relatively conventional and configured substantially in accordance with U.S. Pat. No. 4,889,521 to Nagano. Thus, the configurations and functions of the down shift teeth F_3–I_3 will not be discussed or illustrated in detail herein. Similarly, the configurations and functions of the remaining teeth J_3–K_3 are also not as important to the present invention. Accordingly, the configurations and functions of the remaining teeth J_3–K_3 will not be discussed or illustrated in detail herein. Rather, the

following description will focus on the configuration and function of the up shift teeth A_3–E_3.

The up shift teeth A_3–E_3 are trimmed so that the chain **23** can be smoothly up shifted to the adjacent sprocket S_2. More specifically, the tooth A_3 is a first up shift tooth. The tooth B_3 is a second up shift tooth located adjacent the first up shift tooth A_3. The tooth C_3 is a third up shift tooth located adjacent the second up shift tooth B_3. The tooth D_3 is a fourth up shift tooth located adjacent the third up shift tooth C_3. The tooth E_3 is a fifth up shift tooth located adjacent the fourth up shift tooth D_3.

The first, second and third up shift teeth A_3–C_3 are further dimensioned to prevent an up shifting of the chain **23** when a pair of the outer link plates **23***b* of the bicycle chain **23** meshes with the second up shift tooth B_3. In particular, A_3 and C_3 are dimensioned to maintain alignment of the bicycle chain **23** with the sprocket body **40** to prevent an up shifting of the chain **23** when a pair of the outer link plates **23***b* of the bicycle chain **23** meshes with the second up shift tooth B_3. However, the first, second and third up shift teeth A_3–C_3 are further dimensioned to permit the up shifting of the bicycle chain **23** when a pair of inner link plates **23***a* meshes with the second up shift tooth B_3. In other words, the sprocket S_3 has an odd number of teeth, and thus, the inner and outer link plates **23***a* and **23***b* will alternately engage different teeth with each rotation of the sprocket assembly **12**. Therefore, the teeth of the S_3, will alternately engage both the inner and outer link plates **23***a* and **23***b* and will only permit up shifting if a pair of inner link plates **23***a* meshes with the second up shift tooth B_3.

Referring now to FIGS. **7**A–**7**C, the first up shift tooth A_3 preferably has a base portion defined by a pair of flat side surfaces (up shift surfaces) **41***a* and **41***b*, and a tip portion defined by a pair of angled surfaces **42***a* and **42***b*. The angled or tapered surfaces **42***a* and **42***b* extend to a centrally located circumferential tip surface **43**. A tooth tip is formed by the two angled surfaces **42***a* and **42***b* and the circumferential tip surface **43**.

The flat side surfaces **41***a* and **41***b* extend radially outwardly from the outer periphery of the sprocket body **40** and are substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. The two of flat side surfaces **41***a* and **41***b* are also preferably substantially level or aligned with the small and large sprocket sides **40***a* and **40***b*, respectively. The flat side surfaces **41***a* and **41***b* of the first up shift tooth A_3 form a chain alignment portion of the first up shift tooth A_3. In other words, when a pair of inner link plates **23***a* are located on the first up shift tooth A_3, the flat side surfaces **41***a* and **41***b* engage the inner link plates **23***a* to prevent lateral or axial movement of the chain **23** relative to the sprocket body **40**.

The tooth tip of the first up shift tooth A_3 is illustrated as a common or regular tooth tip. In other words, the tip surface **43** is centrally located midway between the sprocket sides **40***a* and **40***b*, and extends parallel to the sprocket sides **40***a* and **40***b*. Alternatively, one or both of the flat side surfaces **41***a* and **41***b* can be trimmed to form chamfered surfaces such as shown in FIG. **7** of U.S. Pat. No. 4,889,521 to Nagano. Also, the tip surface **43** can be offset to the small sprocket side **40***a* of the sprocket body **40** such as in the second embodiment of the present invention.

Referring now to FIGS. **8**A–**8**C, the second up shift tooth B_3 is configured to permit chain **23** to shift to the small sprocket side **40***a* of the sprocket body **40** when a pair of inner link plates **23** a are engaged therewith. The second up shift tooth B_3 preferably has a base portion defined by a pair of flat side surfaces **45***a* and **45***b*, and a tip portion defined by a pair of angled surfaces **46***a* and **46***b*. The angled or tapered surfaces **46***a* and **46***b* extend to a circumferential extending tip surface **47**. The two angled surfaces **46***a* and **46***b* can be trimmed to form chamfered surfaces that allow the chain **23** to easily move on or off of the tooth B_3.

A tooth tip is formed by the two angled surfaces **46***a* and **46***b* and the circumferential tip surface **47**. In this embodiment, the tip surface **47** extends substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. Moreover, the tip surface **47** is offset to the small sprocket side **40***a* of the sprocket body **40** as seen in FIG. **8**B.

The flat side surfaces **45***a* and **45***b* extend radially outwardly from the outer periphery of the sprocket body **40**, and are substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. The flat side surface **45***a* is also preferably substantially level or aligned with the small sprocket side **40***a*. The flat side surface **45***b*, on the other hand, is recessed from the large sprocket side **40***b* to form an up shift lean recess **48**.

The up shift lean recess **48** that is sized to accommodate one of the inner link plates **23***a*. In other words, the up shift lean recess **48** allows the inner link plate **23***a* of the chain **23** to shift to the small sprocket side **40***a* of the sprocket body **40** as seen in FIG. **22**. Thus, the up shift lean recess **48** allows the chain **23** to be shift laterally or axially relative to the small sprocket side **40***a* of the sprocket body **40** to permit an up shift. The up shift lean recess **48** is preferably circumferentially slanted to become deeper as the up shift lean recess **48** approaches the third up shift tooth C_3. The outer periphery of the sprocket body **40** defines a root diameter of the second up shift tooth B_3, with the up shift lean recess **48** being located mainly radially outward of the root diameter. A portion of the up shift lean recess **48** also lies inside of the root diameter of the second up shift tooth B_3 to form an inner link plate escape **49**. The inner link plate escape **49** has a curvature that substantially matches the curvature of the portions of the inner link plates **23***a* the contact this area.

Referring now to FIGS. **9**A–**9**C, preferably, the third up shift tooth C_3 has a base portion defined by a pair of flat side surfaces **51***a* and **51***b*, and a tip portion defined by a pair of angled surfaces **52***a* and **52***b* and a flat radially extending surface **52***c*. The angled surfaces **52***a* and **52***b* and radially extending surface **52***c* converge to form a circumferentially extending tip surface **53**. A tooth tip is formed by these surfaces **52***a*, **52***b*, **52***c* and **53**.

The flat side surfaces **51***a* and **51***b* extend radially outwardly from the outer periphery of the sprocket body **40** and are substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. The two of flat side surfaces **51***a* and **51***b* are also preferably substantially level or aligned with the small and large sprocket sides **40***a* and **40***b*, respectively. The flat side surfaces **51***a* and **51***b* of the third up shift tooth C_3 form a chain alignment portion of the third up shift tooth C_3. In other words, when a pair of inner link plates **23***a* are located on the third up shift tooth C_3, the flat side surfaces **51***a* and **51***b* engage the inner link plates **23***a* to prevent lateral or axial movement of the chain **23** relative to the sprocket body **40**. Since the first and third up shift teeth A_3 and C_3 are only spaced apart by the second up shift tooth B_3, the first and third up shift teeth A_3 and C_3 both either engage the inner link plates **23***a* of the chain **23** or the outer link plates **23***b* of the chain **23**. When the inner link plates **23***a* of the chain **23** are engaged with the first and third up shift teeth A_3 and C_3, the chain **23** can not shift laterally into the up shift lean recess **48** of the second up shift tooth B_3.

The angled surfaces **52***a* and **52***b* and radially extending surface **52***c* form a notch top that guides the inner link plates **23***a* toward the larger sprocket side **40***b*, the link plates **23***a* are engaging the third up shift tooth C_3. This further ensures that the chain **23** will not be up shifted when the link plates **23***a* are engaging the third up shift tooth C_3.

The tooth tip surface **53** extends substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. Moreover, the tip surface **53** is offset to the small sprocket side **40***a* of the sprocket body **40** as seen in FIG. **9**B.

Referring now to FIG. **9**C, the third up shift tooth C_3 has a pitch formed between the third up shift tooth C_3 and the fourth up shift tooth D_3 that is larger than the pitch formed between the second up shift tooth B_3 and the third up shift tooth C_3. In other words, the rearward edge of the third up shift tooth C_3 is trimmed so that the width W_1 of the third up shift tooth C_3 is smaller than the other up shift teeth that have a width W_2.

Referring now to FIGS. **10**A–**10**C, the fourth up shift tooth D_3 is configured with an inner link plate escape to permit chain **23** to slide between sprockets S_3 and S_2 during an up shift. Specifically, the fourth up shift tooth D_3 has a base portion defined by a pair of flat side surfaces **55***a* and **55***b* that extend radially outwardly from the outer periphery of the sprocket body **40** and are substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. The small sprocket side **40***a* of the fourth up shift tooth D_3 further has a further recessed surface **58** that extends radially outwardly from the outer periphery of the sprocket body **40** and is substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**.

The flat side surface **55***a* forms an inner link plate guide surface. The inner link plate guide surface **55***a* is recessed from the small sprocket side **40***a* of the sprocket body **40**. The large sprocket side **40***b* of the fourth up shift tooth D_3 has a flat side surface **55***b* that extends radially outwardly from the outer periphery of the sprocket body **40** and is substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. The flat side surface **55***b* is also preferably substantially level or aligned with the large sprocket side **40***b*.

Chamfered surfaces **56***a* and **56***b* taper outwardly from the inner link plate guide surface **55***a* and the flat side surface **55***b* to a circumferential tip surface **57**. The tip surface **57** is thinner than the tip surface **43** of the first up shift tooth A_3. The tip surface **57** extends substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. Moreover, the tip surface **57** is offset to the large sprocket side **40***b* of the sprocket body **40** as seen in FIG. **10**B.

The chamfered surface **56***a* forms an inner link plate top guide surface that urges the chain towards the small sprocket side **40***a* when the inner link plates **23***a* engage the fourth up shift tooth D_3.

At the inner edge of the inner link plate guide surface **55***a* is a curved surface **59** that forms the inner link plate escape to permit chain **23** to slide between sprockets S_3 and S_2 during an up shift. The curved surface **59** has a curvature that substantially matches the curvature of the portion of the inner link plates **23***a* that contact this area.

Referring now to FIGS. **11**A–**11**C, the fifth up shift E_3 preferably has a base portion defined by a pair of flat side surfaces **61***a* and **61***b* and one angled surface **62***b* extending from the flat side surface **61***b* to form a circumferentially extending tip surface **63**. As seen in FIGS. **11**A and **11**B, the angled surface **62***b* can be trimmed to form chamfered surfaces that allow the chain **23** to easily move on or off of the tooth E_3. The tip surface **63** is disposed adjacent the large sprocket side **40***b* of the sprocket S_3. Preferably, the tip surface **63** of the tooth E_3 extends parallel to the first and second axial sides **40***a* and **40***b* of the sprocket body **40** and is offset to the large sprocket side **40***b* of the sprocket S_3.

The flat side surfaces **61***a* and **61***b* extend radially outwardly from the outer periphery of the sprocket body **40**, and are substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. The flat side surface **61***b* is also preferably substantially level or aligned with the large sprocket side **40***b*. The flat side surface **61***a*, on the other hand, is recessed from the small sprocket side **40***a*. Thus, the side surface **61***a* on the small sprocket side **40***a* of the tooth E_3 lies on the same level as recessed surface **58** of the fourth up shift tooth D_3 to form an outer link plate escape or a second up shift recess.

The five consecutive teeth F_3–I_3 are down shift teeth that work together to control the down shifting of the chain **23** and form a first down shift path. The down shift teeth F_3–I_3 are disposed immediately behind the up shift teeth A_3–E_3 relative to the direction of rotation R.

Referring again to FIGS. **5** and **6**, the down shift tooth F_3 has a first down shift guide recess **71** formed in the small sprocket side **40***a* of down shift tooth F_3. The down shift tooth G_3 has a second down shift guide recess **72** formed in the small sprocket side **40***a* of down shift tooth G_3. In this embodiment, second down shift guide recess **72** is deeper than the first down shift guide recess **71** relative to the small sprocket side **40***a* of the sprocket body **40**.

The down shift tooth H_3 is considered the first down shift tooth in that it is designed to be the first down shift tooth to catch or fully engage the chain **23**. The small sprocket side **40***a* of down shift tooth H_3 has a base portion with a flat surface **80***a* and a recess **81***a* The flat surface **80***a* extends radially outwardly from the outer periphery of the sprocket body **40** and is substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**. The flat side surface **80***a* is also preferably substantially level or aligned with the small sprocket side **40***a*. The recess **81***a* is preferably slanted to be deeper on the edge that is closest to the down shift teeth **13**. The down shift tooth H_3 preferably has a first down shift lean recess **81***b* formed on the large sprocket side **40***b* of the sprocket body **40**. The first down shift lean recess **81***b* is preferably slanted to be deeper on the edge that is closest to the down shift teeth G_3.

Each of down shift teeth I_3 preferably has a base portion with a flat surface **84***a* that extends radially outwardly from the outer periphery of the sprocket body **40**. The flat surface **84***a* is angled relative to the sprocket side **40***a* of the sprocket body **40**. The flat side surface **84***a* is preferably slanted to be deeper on the edge that is closest to the down shift teeth H_3.

Each of teeth J_3 preferably has a recess **85***a* on the small sprocket side **40***a* of the sprocket body **40**. These recesses **85***a* are designed to prevent interference with the inner link plates **23***a* during down shifting of the chain **23**. In other words, the chain **23** is twisted to curve laterally during a down shifting from the smaller sprocket S_2 to the larger sprocket S_3. This twisting of the chain **23** causes the outer link plates of chain **23** to first mesh with down shift tooth H_3 and then mesh with down shift teeth I_3. Thus, the chain **23** is further twisted laterally in the direction of the large sprocket side **40***b* of the sprocket body **40** to be finally aligned with the sprocket body **40**. This second curve of the chain **23** is offset to the large sprocket side **40***b* of the sprocket body **40** so that one of the inner link plates **23***a* is received in the recesses **85***a* of the teeth J_3.

The teeth K_3 are common teeth that drive the chain **23**. The teeth K_3 do not any specific function during the down shifting or the up shifting in accordance with the present invention. Thus, the teeth K_3 will not be discussed or illustrated herein in detail.

Referring now to FIGS. **12–15**, the sprocket S_4 has seventeen teeth and has similarly shaped teeth to the fifteen teeth sprocket S_3, discussed above. The main difference between the seventeen teeth sprocket S_4 and the fifteen teeth sprocket S_3, discussed above, is that the seventeen teeth sprocket S_4 has two extra common teeth K_4. In view of the similarity between the seventeen teeth sprocket S_4 and the fifteen teeth sprocket S_3, the teeth of the seventeen teeth sprocket S_4 that have the same function as the teeth of the fifteen teeth sprocket S_3 are given the identical reference numerals, but a different subscript number. Thus, the teeth of the seventeen teeth sprocket S_4 will not be discussed in detail herein.

The sprocket S_4 basically has a sprocket body **40** and a plurality (seventeen) of circumferentially spaced teeth A_4–K_4 extending radially and outwardly from an outer periphery of the sprocket body **40**. The sprocket body **40** of the sprocket S_4 has a first axial side or small sprocket side **40*a*** that faces the next smaller sprocket S_3 and a second axial side or large sprocket side **40*b*** that faces the next larger sprocket S_5. The center of the sprocket S_4 is provided with a splined bore **40*c*** that is mounted on the freewheel of the rear hub (not shown) in a conventional manner.

Selected teeth of sprocket S_4 are trimmed in substantially the same manner as sprocket S_3, explained above, so that the chain **23** can be smoothly up shifted or down shifted to the adjacent sprockets S_3 and S_5. The consecutive teeth A_4–E_4 are up shift teeth that work together to control the up shifting of the chain **23** and form a first up shift path. The consecutive teeth F_4–I_4 are down shift teeth that work together to control the down shifting of the chain **23** and form a first down shift path. While the sprocket S_4 is illustrate with only one up shift path and only one down shift path, it will be apparent to those skilled in the bicycle art from this disclosure that the sprocket S_4 can be provided with two up shift paths and two down shift path.

Referring now to FIGS. **16** and **17**, the sprocket S_5 has twenty-one teeth and has similarly shaped teeth to the fifteen teeth sprocket S_3, discussed above. The main difference between the twenty-one teeth sprocket S_5 and the fifteen teeth sprocket S_3, discussed above, is that the twenty-one teeth sprocket S_5 has one up shift path and two down shift paths.

In view of the similarity between the twenty-one teeth sprocket S_5 and the fifteen teeth sprocket S_3, the teeth of the twenty-one teeth sprocket S_5 that have the same function as the teeth of the fifteen teeth sprocket S_3 are given the identical reference numerals, but a different subscript number. Thus, the teeth of the twenty-one teeth sprocket S_5 will not be discussed in detail herein.

The sprocket S_5 basically has a sprocket body **40** and a plurality (twenty-one) of circumferentially spaced teeth A_5–K_5 extending radially and outwardly from an outer periphery of the sprocket body **40**. The sprocket body **40** of the sprocket S_5 has a first axial side or small sprocket side **40*a*** that faces the next smaller sprocket S_4 and a second axial side or large sprocket side **40*b*** that faces the next larger sprocket S_6.

The center of the sprocket S_5 is provided with a splined bore **40*c*** that is mounted on the freewheel of the rear hub (not shown) in a conventional manner.

Selected teeth of sprocket S_5 are trimmed in substantially the same manner as sprocket S_3, explained above, so that the chain **23** can be smoothly up shifted or down shifted to the adjacent sprockets S_4 and S_6. The one consecutive set of teeth A_5–E_5 are up shift teeth that work together to control the up shifting of the chain **23** and form the up shift path. The up shift teeth B_5–E_5 of the sprocket S_5 are substantially identically to the teeth B_3–E_3 of the sprocket S_3, discussed above. The up shift tooth A_5 of the sprocket S_5 is different from the first up shift tooth A_3 of the sprocket S_3, discussed above. Rather, the up shift tooth A_5 of the sprocket S_5 has a recess on its small sprocket side **40*a***. In other words, the up shift tooth A_5 of the sprocket S_5 is similar to the teeth J_3 of the sprocket S_3, discussed above. The two consecutive sets of teeth F_5–I_5 are down shift teeth that work together to control the down shifting of the chain **23** and form the two down shift paths. The teeth F_5–I_5 of the sprocket S_5 are substantially identically to the teeth F_3–I_3 of the sprocket S_3, discussed above.

SECOND EMBODIMENT

Referring now to FIGS. **23–39**, a sprocket assembly **12'** will now be discussed in accordance with a second embodiment of the present invention. In this second embodiment, the sprocket assembly **12'** is an eight stage sprocket assembly with sprockets S_1'–S_8' being spaced from each other at a predetermined interval.

In this second embodiment, the multistage sprocket assembly **12'** of the invention has a teeth configuration of **11T-13T-15T-17T-21T-25T-29T-33T** for the sprockets S_1'–S_8', respectively. Of course, it will be apparent to those skilled in the bicycle art from this disclosure that the sprockets S_1'–S_8' can have other teeth configurations. The present invention is optimized for a sprocket having a total number of teeth equaling an odd number. Of course, it will be apparent to those skilled in the bicycle art that the sprockets of the present invention can be configured with a total number of teeth equaling an even number, as discussed below.

The sprocket assembly **12'** of the second embodiment uses many of the features of the sprocket assembly **12** of the first embodiment. Thus, only the differences of the sprocket assembly **12'** from sprocket assembly **12** of the first embodiment will be discussed and/or illustrated herein. In view of the similarity between this embodiment and the sprockets of the first embodiment, the teeth of this embodiment that have substantially the same function as the teeth of the prior embodiment are given the identical referential numerals as the first embodiment but with a single prime ('). Thus, explanations of these similar teeth and their operations will be omitted from this embodiment.

The sprocket S_3' mainly differs from that of sprockets S_3 in that the up shifting path and the down shifting path overlap. Thus, in this embodiment, the down shift teeth are disposed forward of the up shift teeth relative to the direction of rotation. In other words, the first up shift tooth A_3 and the second down shift tooth I_3 are formed as a first integrated (up/down shift) tooth AI_3', and the second up shift tooth B_3 and the third down shift tooth I_3 are formed as a second integrated (up/down shift) tooth BI_3'. However, the second integrated tooth BI_3' is basically identical to the second up shift tooth B_3. Also, up shift tooth C_3'–E_3' have been modified in the sprocket S_3'. Therefore, only teeth AI_3', C_3', and D_3' will be discussed in detail below.

Referring now to FIGS. **26A–26C**, the first integrated tooth AI_3' preferably has a base portion defined by a pair of

flat side surfaces (up shift surfaces) **41***a*' and **41***b*', and a tip portion defined by a pair of angled surfaces **42***a*' and **42***b*'. The angled or tapered surfaces **42***a*' and **42***b*' form a circumferential extending tip surface **43**'. A tooth tip is formed by the two angled surfaces **42***a*' and **42***b*' and the circumferential tip surface **43**'. The tooth tip of the first integrated tooth AI_3' extends parallel to the sprocket sides **40***a*' and **40***b*'. Also, the tip surface **43**' is offset to the small sprocket side **40***a*' of the sprocket body **40**'.

The flat side surfaces **41***a*' and **41***b*' extend radially outwardly from the outer periphery of the sprocket body **40**'. The flat side surface **41***a*' is substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**', while the flat side surface **41***b*' is angled or slanted relative to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. The flat side surface **41***a*' is also preferably substantially level or aligned with the small sprocket side **40***a*', while the flat side surface **41***b*' has a trailing edge **44**' that is substantially aligned with the large side **40***b*' of the sprocket body **40**'. This trailing edge **44**' extends substantially radially from the large sprocket side **40***b*' of the sprocket body **40**'. In other words, the flat side surface **41***b*' is angled or slanted relative to the large sprocket side **40***b*' of the sprocket body **40**' to form a recess. The recess formed by the flat side surface **41***b*' is flush with the large sprocket side **40***b*' at the trailing edge **44**' that is adjacent to the second integrated tooth BI_3' and deeper at the leading edge that is adjacent to the down shift tooth H_3'.

The flat side surface **41***a*' and the edge **44**' of the first integrated tooth AI_3' form a chain alignment portion of the first integrated tooth AI_3'. In other words, when a pair of inner link plates **23***a* are located on the first integrated tooth AI_3', the flat side surface **41***a*' and the edge **44**' engage the inner link plates **23***a* to prevent lateral or axial movement of the chain **23** relative to the sprocket body **40**'.

Referring now to FIGS. **27**A–**27**C, the second integrated tooth BI_3' is configured to permit chain **23** to shift to the small sprocket side **40***a*' of the sprocket body **40**' when a pair of inner link plates **23***a* are engaged therewith. The second integrated tooth BI_3' preferably has a base portion defined by a pair of flat side surfaces **45***a*' and **45***b*', and a tip portion defined by a pair of angled surfaces **46***a*' and **46***b*'. The angled or tapered surfaces **46***a*' and **46***b*' extend to a circumferential extending tip surface **47**'. The two angled surfaces **46***a*' and **46***b*' can be trimmed to form chamfered surfaces that allow the chain **23** to easily move on or off of the second integrated tooth BI_3'.

A tooth tip is formed by the two angled surfaces **46***a*' and **46***b*' and the circumferential tip surface **47**'. In this embodiment, the tip surface **47**' extends substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. Moreover, the tip surface **47**' is offset to the small sprocket side **40***a* of the sprocket body **40**' as seen in FIG. **27**B.

The flat side surfaces **45***a*' and **45***b*' extend radially outwardly from the outer periphery of the sprocket body **40**', and are substantially parallel to the sprocket sides **40***a* and **40***b* of the sprocket body **40**'. The flat side surface **45***a*' is also preferably substantially level or aligned with the small sprocket side **40***a*'. The flat side surface **45***b*', on the other hand, is recessed from the large sprocket side **40***b*' to form an up shift lean recess **48**'.

The up shift lean recess **48**' that is sized to accommodate one of the inner link plates **23***a*. In other words, the up shift lean recess **48**' allows the inner link plate **23***a* of the chain **23** to shift to the small sprocket side **40***a*' of the sprocket body **40**' as seen in FIG. **39**. Thus, the up shift lean recess **48**' allows the chain **23** to be shift laterally or axially relative to the small sprocket side **40***a*' of the sprocket body **40**' to permit an up shift The up shift lean recess **48**' is preferably circumferentially slanted to become deeper as the up shift lean recess **48**' approaches the third up shift tooth C_3'. The outer periphery of the sprocket body **40**' defines a root diameter of the second integrated tooth BI_3', with the up shift lean recess **48**' being located mainly radially outward of the root diameter. A portion of the up shift lean recess **48**' also lies inside of the root diameter of the second integrated tooth BI_3' to form an inner link plate escape **49**'. The inner link plate escape **49**' has a curvature that substantially matches the curvature of the portions of the inner link plates **23***a* that contact this area.

Referring now to FIGS. **28**A–**28**C, preferably, the third up shift tooth C_3' has a base portion defined by an angled surface **50**' and a pair of flat side surfaces **51***a*' and **51***b*'. The third up shift tooth C_3' has a tip portion defined by a pair of angled surfaces **52***a*' and **52***b*' and a flat radially extending surface **52***c*'. The angled surfaces **52***a*' and **52***b*' and radially extending surface **52***c*' converge to form a circumferentially extending tip surface **53**'. A tooth tip is formed by these surfaces **52***a*', **52***b*', **52***c*' and **53**'.

The flat side surfaces **51***a*' and **51***b*' extend radially outwardly from the outer periphery of the sprocket body **40**' and are substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. The two flat side surfaces **51***a*' and **51***b*' are also preferably substantially level or aligned with the small and large sprocket sides **40***a*' and **40***b*', respectively. The flat side surfaces **51***a*' and **51***b*' of the third up shift tooth C_3' form a chain alignment portion of the third tooth C_3'. In other words, when a pair of inner link plates **23***a* are located on the third tooth C_3', the flat side surfaces **51***a*' and **51***b*' engage the inner link plates **23***a* to prevent lateral or axial movement of the chain **23** relative to the sprocket body **40**'. Since the first and third up shift teeth AI_3' and C_3' are only spaced apart by the second integrated tooth BI_3', the first and third up shift teeth AI_3' and C_3' both either engage the inner link plates **23***a* of the chain **23** or the outer link plates **23***b* of the chain **23**. When the inner link plates **23***a* of the chain **23** are engaged with the first and third up shift teeth AI_3' and C_3', the chain **23** can not shift laterally into the up shift lean recess **48**' of the second integrated tooth BI_3'.

The angled surfaces **52***a*' and **52***b*' and radially extending surface **52***c*' form a notch top that guides the inner link plates **23***a* toward the larger sprocket side **40***b*', the link plates **23***a* are engaging the third up shift tooth C_3'. This further ensures that the chain **23** will not be up shifted when the link plates **23***a* are engaging the third up shift tooth C_3'.

The tooth tip surface **53**' extends substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. Moreover, the tip surface **53**' is offset to the small sprocket side **40***a*' of the sprocket body **40**' as seen in FIG. **28**B.

Referring now to FIG. **28**C, the third up shift tooth C_3' has a pitch formed between the third up shift tooth C_3' and the fourth up shift tooth D_3' that is larger than the pitch formed between the second integrated tooth BI_3' and the third up shift tooth C_3'. In other words, the rearward edge of the third up shift tooth C_3' is trimmed so that the width W_1' of the third up shift tooth C_3' is smaller than the other up shift teeth that have a width W_2'.

Referring now to FIGS. **29**A–**29**C, the fourth up shift tooth D_3' is configured with an inner link plate escape to permit chain **23** to slide between sprockets S_3' and S_2' during an up shift. Specifically, the fourth up shift tooth D_3' has a

base portion defined by a pair of flat side surfaces **55***a*' and **55***b*' that extend radially outwardly from the outer periphery of the sprocket body **40**' and are substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. The small sprocket side **40***a*' of the fourth up shift tooth D_3' further has a further recessed surface **58**' that extends radially outwardly from the outer periphery of the sprocket body **40**' and is substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. The recess **58**' extend to the fifth up shift tooth E_3' to form an outer link plate escape or a second up shift recess.

The flat side surface **55***a*' forms an inner link plate guide surface. The inner link plate guide surface **55***a*' is recessed from the small sprocket side **40***a*' of the sprocket body **40**'. The large sprocket side **40***b*' of the fourth up shift tooth D_3' has a flat side surface **55***b*' that extends radially outwardly from the outer periphery of the sprocket body **40**' and is substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. The flat side surface **55***b*' is also preferably substantially level or aligned with the large sprocket side **40***b'*.

Chamfered surfaces **56***a*' and **56***b*' taper outwardly from the inner link plate guide surface **55***a*' and the flat side surface **55***b*' to a circumferential tip surface **57**'. The tip surface **57**' is thinner than the tip surface **43**' of the first integrated tooth AI_3'. The tip surface **57**' extends substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. Moreover, the tip surface **57**' is offset to the large sprocket side **40***b*' of the sprocket body **40**' as seen in FIG. **29**B.

The chamfered surface **56***a*' forms an inner link plate top guide surface that urges the chain towards the small sprocket side **40***a*' when the inner link plates **23***a* engage the fourth up shift tooth D_3'.

At the inner edge of the inner link plate guide surface **55***a* is a curved surface **59**' that forms the inner link plate escape to permit chain **23** to slide between sprockets S_3 and S_2 during an up shift. The curved surface **59**' has a curvature that substantially matches the curvature of the portion of the inner link plates **23***a* that contact this area.

Referring now to FIGS. **30**A–**30**C, the fifth up shift E_3' preferably has a base portion defined by a pair of flat side surfaces **61***a*' and **61***b*' and one angled surface **62***b*' extending from the flat side surface **61***b*' to form a circumferentially extending tip surface **63**'. As seen in FIGS. **30**A and **30**B, the angled surface **62***b*' can be trimmed to form chamfered surfaces that allow the chain **23** to easily move on or off of the tooth E_3'. The tip surface **63**' is disposed adjacent the large sprocket side **40***b*' of the sprocket S_3'. Preferably, the tip surface **63**' of the tooth E_3 extends parallel to the first and second axial sides **40***a*' and **40***b*' of the sprocket body **40**' and is offset to the large sprocket side **40***b*' of the sprocket S_3'.

The flat side surfaces **61***a*' and **61***b*' extend radially outwardly from the outer periphery of the sprocket body **40**', and are substantially parallel to the sprocket sides **40***a*' and **40***b*' of the sprocket body **40**'. The flat side surface **61***b*' is also preferably substantially level or aligned with the large sprocket side **40***b*'. The flat side surface **61***a*', on the other hand, is recessed from the large sprocket side **40***b*'. Thus, the side surface **61***a*' on the small sprocket side **40***a*' of the tooth E_3' lies on the same level as recessed surface **55***a*' of the fourth up shift tooth D_3'.

Referring now to FIGS. **31** and **32**, the sprocket S_4' has seventeen teeth and has similarly shaped teeth to the seventeen teeth sprocket S_4, discussed above. The main difference between the seventeen teeth sprocket S_4' and the seventeen teeth sprocket S_4, discussed above, is that the seventeen teeth sprocket S_4 has two extra down shift teeth J_4. In view of the similarity between the seventeen teeth sprocket S_4' and the seventeen teeth sprocket S_4, the teeth of the seventeen teeth sprocket S_4' that have the same function as the teeth of the seventeen teeth sprocket S_4 are given the identical reference numerals, but a different subscript number. Thus, the teeth of the seventeen teeth sprocket S_4' will not be discussed in detail herein.

The sprocket S_4' basically has a sprocket body **40**' and a plurality (seventeen) of circumferentially spaced teeth A_4'–K_4' extending radially and outwardly from an outer periphery of the sprocket body **40**'. The sprocket body **40**' of the sprocket S_4' has a first axial side or small sprocket side **40***a*' that faces the next smaller sprocket S_3' and a second axial side or large sprocket side **40***b*' that faces the next larger sprocket S_5'. The center of the sprocket S_4' is provided with a splined bore **40***c*' that is mounted on the freewheel of the rear hub (not shown) in a conventional manner.

Selected teeth of sprocket S_4' are trimmed in substantially the same manner as sprocket S_4, explained above, so that the chain **23** can be smoothly up shifted or down shifted to the adjacent sprockets S_3' and S_5'. The consecutive teeth A_4'–E_4' are up shift teeth that work together to control the up shifting of the chain **23** and form a first up shift path. The consecutive teeth F_4'–I_4' are down shift teeth that work together to control the down shifting of the chain **23** and form a first down shift path. While the sprocket S_4' is illustrate with only one up shift path and only one down shift path, it will be apparent to those skilled in the bicycle art from this disclosure that the sprocket S_4' can be provided with two up shift paths and two down shift path.

Referring now to FIGS. **33** and **34**, the sprocket S_5' has twenty-one teeth and has similarly shaped teeth to the fifteen teeth sprocket S_3', discussed above. The main difference between the twenty-one teeth sprocket S_5' and the fifteen teeth sprocket S_3', discussed above, is that it has more teeth and the tooth E_5' is configured as in the sprocket S_3', i.e., the flat side surface **61***a*' is at the same level as the flat side surface **55***a'*.

In view of the similarity between the twenty-one teeth sprocket S_5' and the fifteen teeth sprockets S_3 and S_3', the teeth of the twenty-one teeth sprocket S_5' that have the same function as the teeth of the fifteen teeth sprocket S_3' are given the identical reference numerals, but a different subscript number. Thus, the teeth of the twenty-one teeth sprocket S_5' will not be discussed in detail herein.

The sprocket S_5' basically has a sprocket body **40** and a plurality (twenty-one) of circumferentially spaced teeth A_5'–K_5' extending radially and outwardly from an outer periphery of the sprocket body **40**'. The sprocket body **40**' of the sprocket S_5' has a first axial side or small sprocket side **40***a*' that faces the next smaller sprocket S_4' and a second axial side or large sprocket side **40***b*' that faces the next larger sprocket S_6'. The center of the sprocket S_5' is provided with a splined bore **40***c*' that is mounted on the freewheel of the rear hub (not shown) in a conventional manner.

Selected teeth of sprocket S_5' are trimmed in substantially the same manner as sprockets S_3 and/or S_3', explained above, so that the chain **23** can be smoothly up shifted or down shifted to the adjacent sprockets S_4' and S_6'.

Referring now to FIGS. **35** and **36**, the sprocket S_6' has twenty-five teeth and has similarly shaped teeth to the twenty-one teeth sprocket S_6', discussed above. The main difference between the twenty-five teeth sprocket S_5' and the twenty-one teeth sprocket S_5', discussed above, is that the

twenty-five teeth sprocket S_6' has two up shift paths and two down shift paths.

In view of the similarity between the twenty-five teeth sprocket S_6 and the sprocket S_5', the teeth of the twenty-five teeth sprocket S_5' that have the same function as the teeth of the sprocket S_5' are given the identical reference numerals, but a different subscript number. Thus, the teeth of the twenty-five teeth sprocket S_6' will not be discussed in detail herein.

The sprocket S_6' basically has a sprocket body **40**' and a plurality (twenty-five teeth) of circumferentially spaced teeth A_6'–K_6' extending radially and outwardly from an outer periphery of the sprocket body **40**'. The sprocket body **40**' of the sprocket S_6' has a first axial side or small sprocket side **40***a*' that faces the next smaller sprocket S_4' and a second axial side or large sprocket side **40***b*' that faces the next larger sprocket S_6'. The center of the sprocket S_6' is provided with a splined bore **40***c*' that is mounted on the freewheel of the rear hub (not shown) in a conventional manner.

SPROCKET WITH EVEN TEETH CONFIGURATION

Referring now to FIGS. **40** and **41**, a sprocket S_5" is illustrated in accordance with the present invention. The sprocket S_5" utilizes the principles of the present invention as discussed relative to the sprockets S_3–S_5. In view of the similarity between this embodiment and the sprockets of the two prior embodiments, the teeth of this embodiment that have the same function as the teeth of the prior embodiment are given the identical referential numerals as the first embodiment but with a double prime ("). Thus, explanations of these similar teeth and their operations will be omitted from this embodiment.

The sprocket S_5" can be used instead of either sprocket S_5 or S_5' in the prior embodiments. The sprocket S_5" basically has a sprocket body **40**" and a plurality (twenty) of circumferentially spaced teeth A_5"–K_5" extending radially and outwardly from an outer periphery of the sprocket body **40**". Thus, the sprocket S_5" has a total number of teeth equaling an even number. Since the sprocket S_5" has an even number of teeth, the sprocket S_5" has two sets of up shift teeth so that a pair of up shift paths are formed. The first set of up shift teeth forming the first up shift path is circumferentially spaced from the second set of up shift teeth forming the second up shift path. The spacing between the two up shift paths is such the only one of the up shift paths can be used depending on how the chain **23** was shifted onto the sprocket S_5". In other words, only one of the second up shift teeth B_5" will be engage with a pair of inner link plates **23***a*, while the other the second up shift teeth B_5" will be engage with a pair of outer link plates **23***b*.

The terms of degree such as “substantially”, “about” and “approximately” as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed. These terms should be construed as including a deviation of ±5% of the modified term if this would not negate the meaning of the word it modifies.

While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. Furthermore, the foregoing description of the embodiments according to the present invention are provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. A sprocket for a multi-stage sprocket assembly of a bicycle comprising:

a sprocket body having a first axial side and a second axial side; and

a plurality of circumferentially spaced teeth extending radially and outwardly from an outer periphery of said sprocket body, said teeth including

a plurality of up shift teeth including a first up shift tooth, a second up shift tooth located adjacent said first up shift tooth and a third up shift tooth located adjacent said second up shift tooth,

said first, second and third up shift teeth being so dimensioned to maintain alignment of a bicycle chain to prevent an up shifting of the chain when an outer link plate of the bicycle chain meshes with said second up shift tooth, and to shift the bicycle chain when an inner link plate meshes with said second up shift tooth along a first up shift path.

2. A sprocket according to claim **1**, wherein

said first up shift tooth has a first flat up shift surface substantially aligned with said second axial side of said sprocket body,

said second up shift tooth has a first up shift lean recess in said second axial side of said sprocket body, and

said third up shift tooth has a second flat up shift surface substantially aligned with said second axial side of said sprocket body.

3. A sprocket according to claim **1**, wherein

said up shift teeth further includes a fourth up shift tooth located adjacent said third up shift tooth such that said first, second, third and fourth up shift teeth form said first up shift path.

4. A sprocket according to claim **3**, wherein

said first up shift tooth has a first flat up shift surface substantially aligned with said second axial side of said sprocket body,

said second up shift tooth has a first up shift lean recess in said second axial side of said sprocket body,

said third up shift tooth has a second flat up shift surface substantially aligned with said second axial side of said sprocket body, and

said fourth up shift tooth has a second up shift recess in said first axial side of said sprocket body forming an inner link plate up shift guide surface.

5. A sprocket according to claim **1**, wherein

said first up shift tooth has a tip that extends substantially parallel to said first and second axial sides of said sprocket body.

6. A sprocket according to claim **5**, wherein

said tip of said first up shift tooth is centered between said first and second axial sides of said sprocket body.

7. A sprocket according to claim **5**, wherein

said tip of said first up shift tooth is offset towards one of said first and second axial sides of said sprocket body.

8. A sprocket according to claim **7**, wherein

said tip of said first up shift tooth is offset towards said first axial side of said sprocket body.

9. A sprocket according to claim **1**, wherein

said second up shift tooth has a tip that extends substantially parallel to said first and second axial sides of said sprocket body.

10. A sprocket according to claim **2**, wherein

said first up shift lean recess of said second up shift tooth is circumferentially slanted to become deeper as said first up shift lean recess approaches said third up shift tooth.

11. A sprocket according to claim 2, wherein
said outer periphery of said sprocket body defines a root diameter of said up shift teeth, and said first up shift lean recess of said second up shift tooth is located radially outward of said root diameter.

12. A sprocket according to claim 2, wherein
said third up shift tooth has a tip that extends substantially parallel to said first and second axial sides of said sprocket body.

13. A sprocket according to claim 12, wherein
said third up shift tooth has a radial height with an inner link plate sliding surface extending along approximately half of said radial height of said third up shift tooth on said second axial side of said sprocket body and being disposed radially outward of said second flat up shift surface.

14. A sprocket according to claim 2, wherein
said third up shift tooth has an inner link plate sliding surface disposed in said second axial side of said sprocket body and disposed radially outward of said second flat up shift surface.

15. A sprocket according to claim 1, wherein
said third up shift tooth has a first up shift surface substantially aligned with said first axial side of said sprocket body.

16. A sprocket according to claim 15, wherein
said third up shift tooth has a second up shift surface substantially aligned with said second axial side of said sprocket body.

17. A sprocket according to claim 16, wherein
said first up shift tooth has a third up shift surface substantially aligned with said first axial side of said sprocket body.

18. A sprocket according to claim 17, wherein
said first up shift tooth has a fourth up shift surface substantially aligned with said second axial side of said sprocket body.

19. A sprocket according to claim 2, wherein
said third up shift tooth has an outer link plate guide surface disposed in said second axial side of said sprocket body, said outer link plate guide surface slanting from said second flat up shift surface as said outer link plate guide surface approaches towards said first axial side of said sprocket body.

20. A sprocket according to claim 3, wherein
said third up shift tooth has a pitch formed between said third up shift tooth and said fourth up shift tooth that is larger than a pitch formed between said second up shift tooth and said third up shift tooth.

21. A sprocket according to claim 3, wherein
said fourth up shift tooth has an inner link plate guide surface formed at its tip and slanted radially inward from said tip of said fourth up shift tooth towards said first axial side of said sprocket body.

22. A sprocket according to claim 21, wherein
said fourth up shift tooth has an inner link plate escape recess formed on said first axial side of said sprocket body and located radially inward of said inner link plate guide surface.

23. A sprocket according to claim 22, wherein
said fourth up shift tooth has an up shift recess disposed on said first axial side of said sprocket body, said up shift recess of said fourth up shift tooth being deeper than said inner link plate escape recess relative to said first axial side of said sprocket body.

24. A sprocket according to claim 3, wherein
said fourth up shift tooth has an inner link plate escape recess formed on said first axial side of said sprocket body.

25. A sprocket according to claim 1, wherein
said teeth include a plurality of down shift teeth that are trimmed to form a first down shift path.

26. A sprocket according to claim 25, wherein
said first axial side of said sprocket body has a first down shift guide recess that extends along at least one of said down shift teeth.

27. A sprocket according to claim 26, wherein
said first axial side of said sprocket body has a second down shift guide recess that extends along at least one of said down shift teeth that is adjacent to said first down shift recess, said second down shift guide recess being deeper than said first down shift recess relative to said first axial side of said sprocket body.

28. A sprocket according to claim 27, wherein
said down shift teeth includes first, second and third down shift teeth that are consecutively arranged to form a part of said first down shift path and disposed behind said first and second down shift guide recesses relative to the direction of rotation.

29. A sprocket according to claim 25, wherein
said down shift teeth includes a first down shift tooth with a first down shift lean recess formed on said second axial side of said sprocket body.

30. A sprocket according to claim 29, wherein
said down shift teeth includes a second down shift tooth with a second down shift lean recess formed in said second axial side of said sprocket body, said second down shift tooth teeth being located adjacent said first down shift tooth.

31. A sprocket according to claim 30, wherein
said down shift teeth includes a third down shift tooth with a third down shift lean recess formed in said second axial side of said sprocket body, said third down shift tooth teeth being located adjacent said second down shift tooth.

32. A sprocket according to claim 31, wherein
said first axial side of said sprocket body has a first down shift guide recess that extends along said down shift teeth that is disposed adjacent and forward of said first down shift tooth relative to the direction of rotation.

33. A sprocket according to claim 32, wherein
said first axial side of said sprocket body has a second down shift guide recess that extends along at least one of said down shift teeth that is adjacent to said first down shift recess, said second down shift guide recess being deeper than said first down shift guide recess relative to said first axial side of said sprocket body.

34. A sprocket according to claim 25, wherein
said down shift teeth are disposed behind said up shift teeth relative to the direction of rotation.

35. A sprocket according to claim 25, wherein
said down shift teeth and said up shift teeth overlap such that at least one said up shift teeth also forms one of said down shift teeth.

36. A sprocket according to claim 35, wherein
two of said up shift teeth also form two of said down shift teeth.

37. A sprocket according to claim 36, wherein
said first up shift tooth and said second down shift tooth are formed as a first integrated tooth, and said second

up shift tooth and said third down shift tooth are formed as a second integrated tooth.

38. A sprocket according to claim **37**, wherein

said first integrated tooth has a substantially radially extending edge that is substantially aligned with said second axial side of said sprocket body.

39. A sprocket according to claim **38**, wherein

said third up shift tooth has a flat up shift surface substantially aligned with a substantially radially extending edge that is substantially aligned with said second axial side of said sprocket body, and a slanted surface extending from said radially extending edge of said flat up shift surface to form a recess on said second axial side of said third up shift tooth.

40. A sprocket according to claim **1**, wherein

said up shift teeth further includes a second up shift path formed by an additional set of up shift teeth that are circumferentially spaced said up shift teeth forming said first up shift path.

41. A sprocket according to claim **40**, wherein

said sprocket body has a total number of said teeth equaling an even number.

42. A sprocket according to claim **40**, wherein

said teeth include a plurality of down shift teeth that are trimmed to form a pair of circumferentially spaced down shift paths.

43. A sprocket according to claim **1**, wherein

said sprocket body has a total number of said teeth equaling an odd number.

44. A sprocket for a multi-stage sprocket assembly of a bicycle comprising:

a sprocket body having a first axial side and a second axial side; and

a plurality of circumferentially spaced teeth extending radially and outwardly from an outer periphery of said sprocket body, said teeth including

a first shift tooth having a first inner link plate alignment surface substantially aligned with said second axial side of said sprocket body and a first down shift lean recess in said second axial side of said sprocket body,

a second shift tooth having an up/down shift lean recess in said second axial side of said sprocket body and being disposed adjacent said first shift tooth in an opposite direction of rotation,

a third tooth having a second inner link plate alignment surface substantially aligned with said second axial side of said sprocket body and being disposed adjacent said second shift tooth in an opposite direction of rotation,

a fourth tooth having a first up shift recess in said first axial side of said sprocket body forming an inner link plate up shift guide surface and being disposed adjacent said third shift tooth in an opposite direction of rotation,

a fifth tooth having a second down shift lean recess in said second axial side of said sprocket body and being disposed adjacent said first shift tooth in the direction of rotation, and

said first, second, third and fourth shift teeth forming an up shift path and said first, second, and fifth shift teeth forming a down shift path.

45. A multi-stage sprocket assembly for a bicycle comprising:

a small sprocket having an outer periphery with a plurality of circumferentially spaced teeth; and

a large sprocket disposed adjacent said small sprocket to rotate together in a direction of rotation, said large sprocket having a sprocket body with a first axial side and a second axial side, and a plurality of circumferentially spaced teeth extending radially and outwardly from an outer periphery of said sprocket body, said teeth of said large sprocket including

a plurality of up shift teeth including a first up shift tooth, a second up shift tooth located adjacent said first up shift tooth and a third up shift tooth located adjacent said second up shift tooth,

said first, second and third up shift teeth being so dimensioned to maintain alignment of a bicycle chain to prevent an up shifting of the chain when an outer link plate of the bicycle chain meshes with said second up shift tooth, and to shift the bicycle chain when an inner link plate meshes with said second up shift tooth along a first up shift path.

46. An automatic shifting assembly for a bicycle comprising:

an automatic shift control unit;

a speed sensing unit operatively coupled to said automatic shift control unit to provide a signal indicate a current speed;

a chain shifting device operatively coupled to said automatic shift control unit to move a chain in response to a shift signal from said automatic shift control unit; and

a multi-stage sprocket assembly including a small sprocket having an outer periphery with a plurality of circumferentially spaced teeth, and a large sprocket disposed adjacent said small sprocket to rotate together in a direction of rotation, said large sprocket having a sprocket body with a first axial side and a second axial side, and a plurality of circumferentially spaced teeth extending radially and outwardly from an outer periphery of said sprocket body, said teeth of said large sprocket including

a plurality of up shift teeth including a first up shift tooth, a second up shift tooth located adjacent said first up shift tooth and a third up shift tooth located adjacent said second up shift tooth,

said first, second and third up shift teeth being so dimensioned to maintain alignment of a bicycle chain to prevent an up shifting of the chain when an outer link plate of the bicycle chain meshes with said second up shift tooth, and to shift the bicycle chain when an inner link plate meshes with said second up shift tooth along a first up shift path.

47. An automatic shifting assembly according to claim **46**, wherein said chain shifting device is a motorized rear derailleur.

48. An automatic shifting assembly according to claim **46**, wherein said speed sensing unit includes a magnet and a magnetically operable sensor.

* * * * *

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(54) CHAMFERED SPROCKET ASSEMBLY

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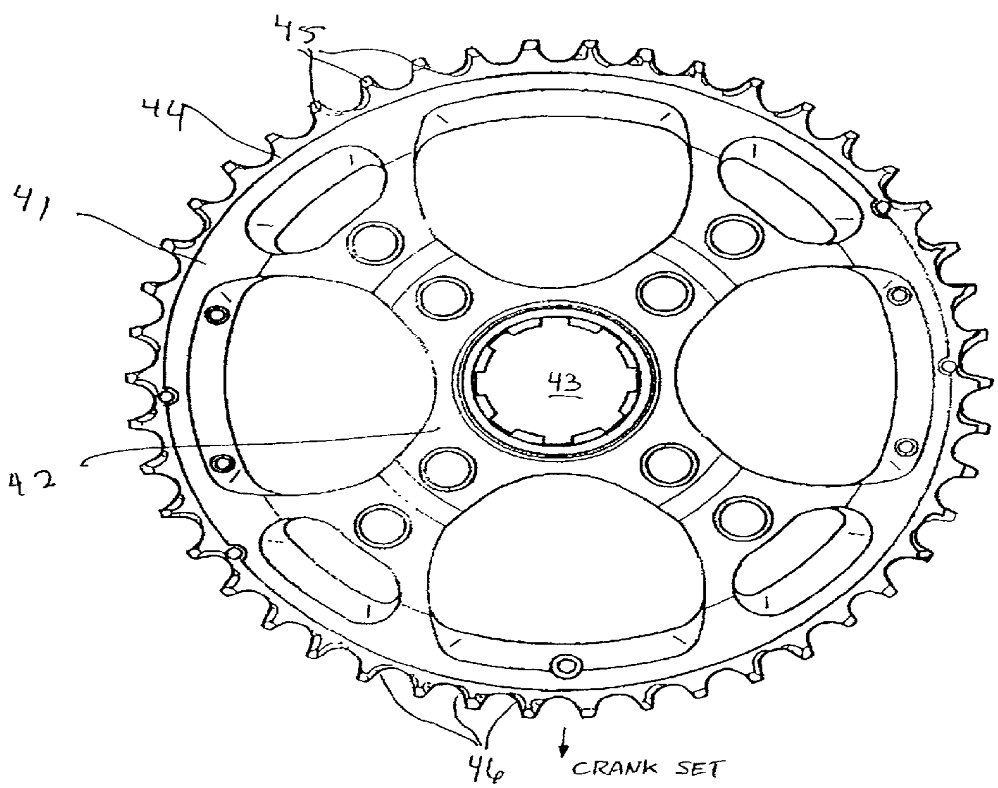
(52) **U.S. Cl.** **474/160**; 474/152; 474/164

(57) **ABSTRACT**

A chamfered sprocket assembly for facilitating the shifting of a drive chain from a larger sprocket to a smaller sprocket is disclosed. In a preferred embodiment, the chamfered sprocket assembly includes a sprocket having a plurality of chamfered portions on a side facing a smaller sprocket, each chamfered portion located between a pair of toothlike projections located on the rim of the sprocket body. The chamfered portions preferably include a crest which tapers toward a first edge and a second edge of the chamfer portion, respectively. The crest is preferably offset from the center of the chamfer portion toward the driving direction of the sprocket assembly. To further facilitate the shifting of the drive chain, the sprocket preferably includes a rounded shoulder to guide the movement of the drive chain. Finally, the friction between the toothlike projections and the drive chain is reduced by polishing the toothlike projections.



Front view of chain ring
46 Teeth.

FIG. 1a

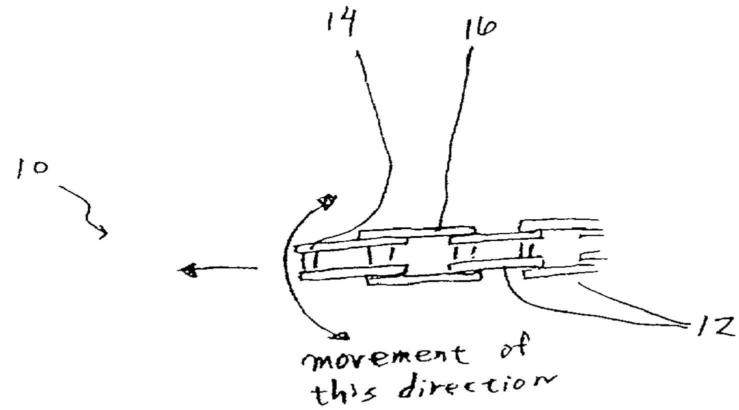


FIG. 1b

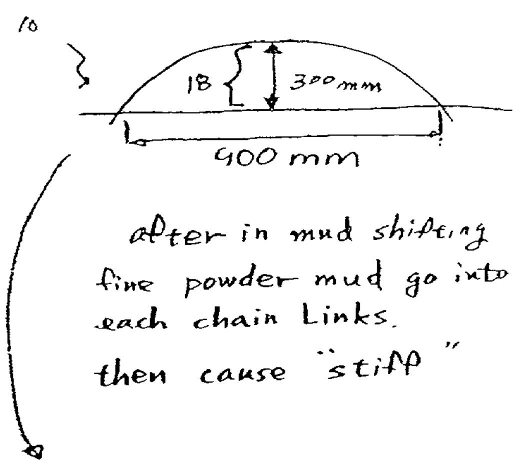


FIG. 1c

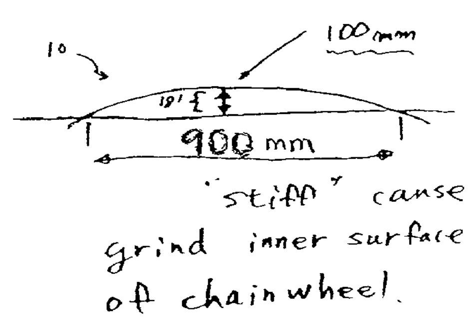
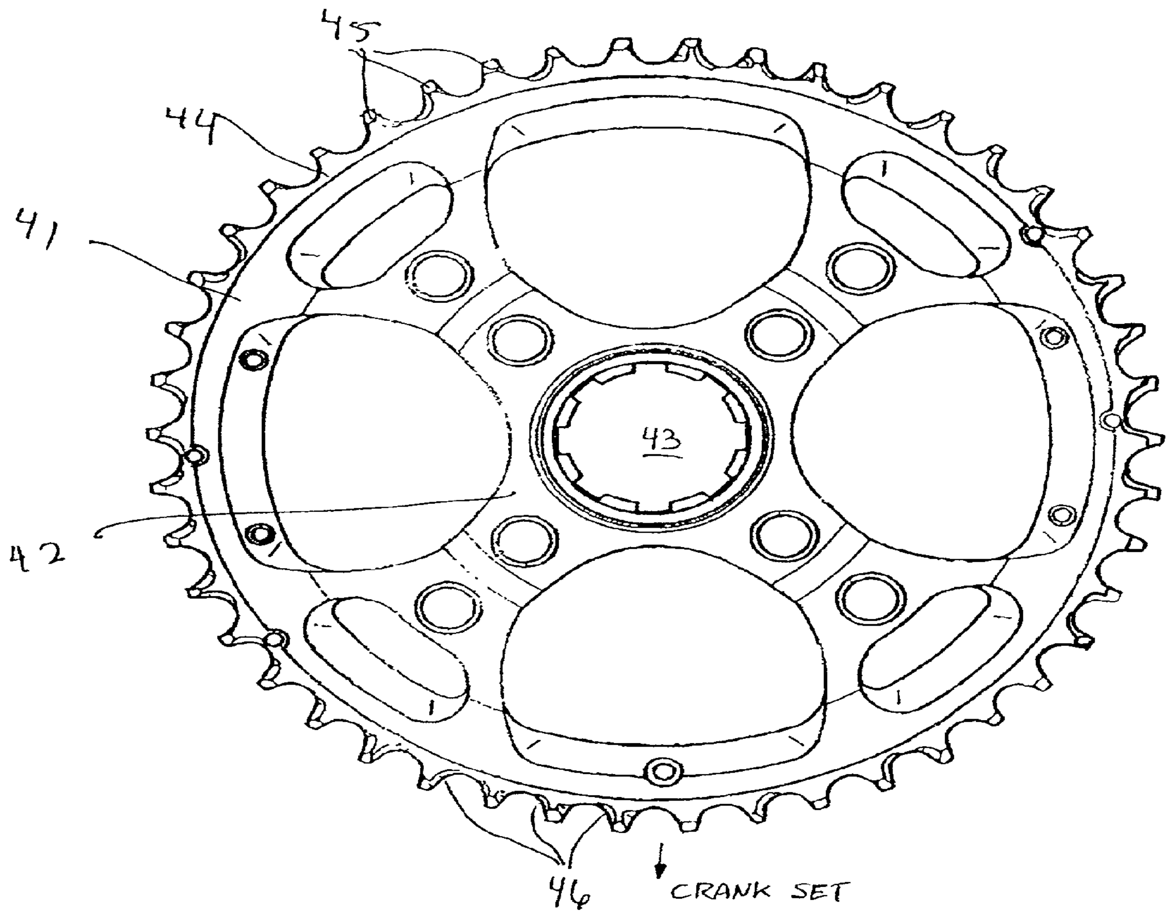
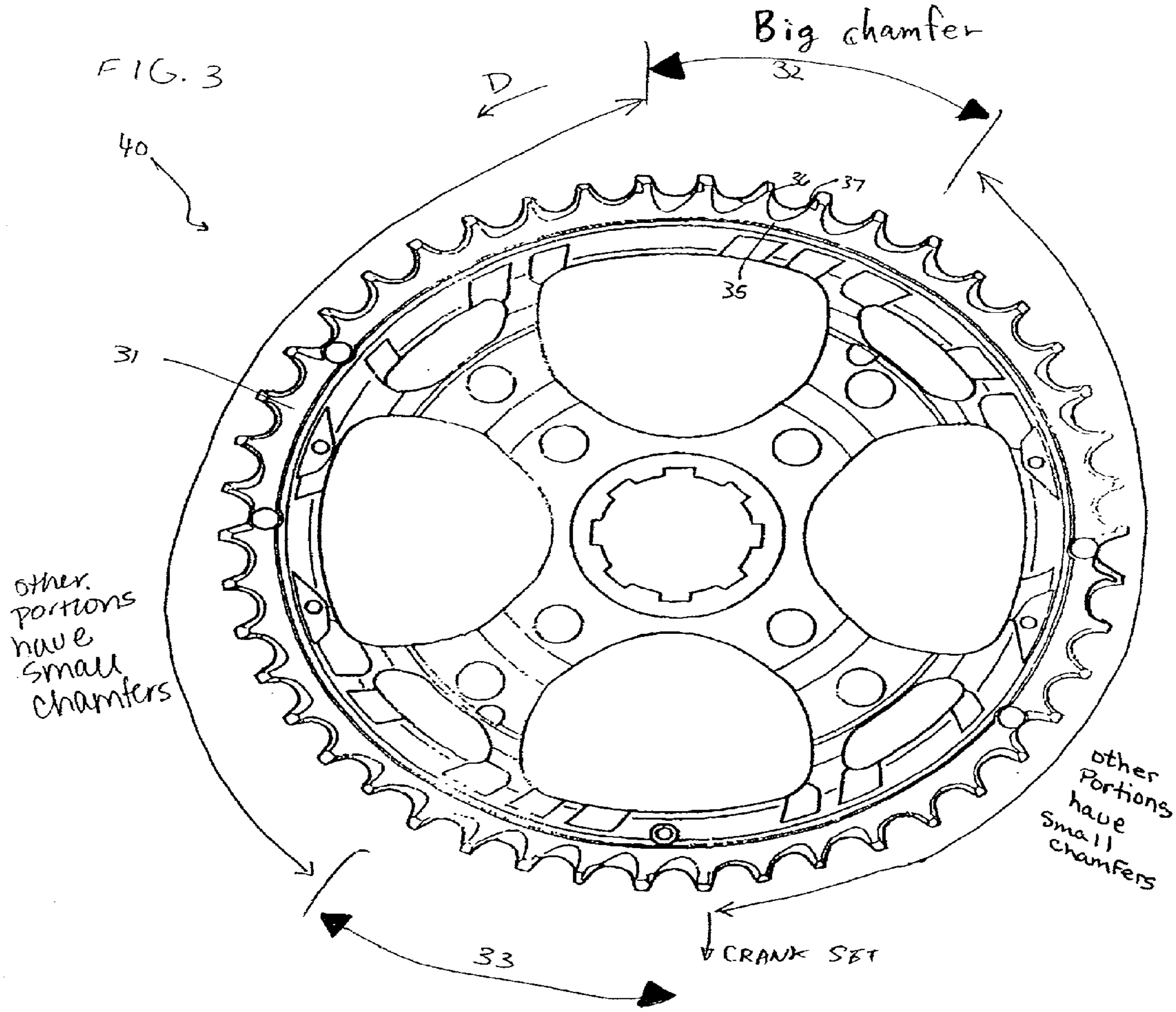


FIG. 2



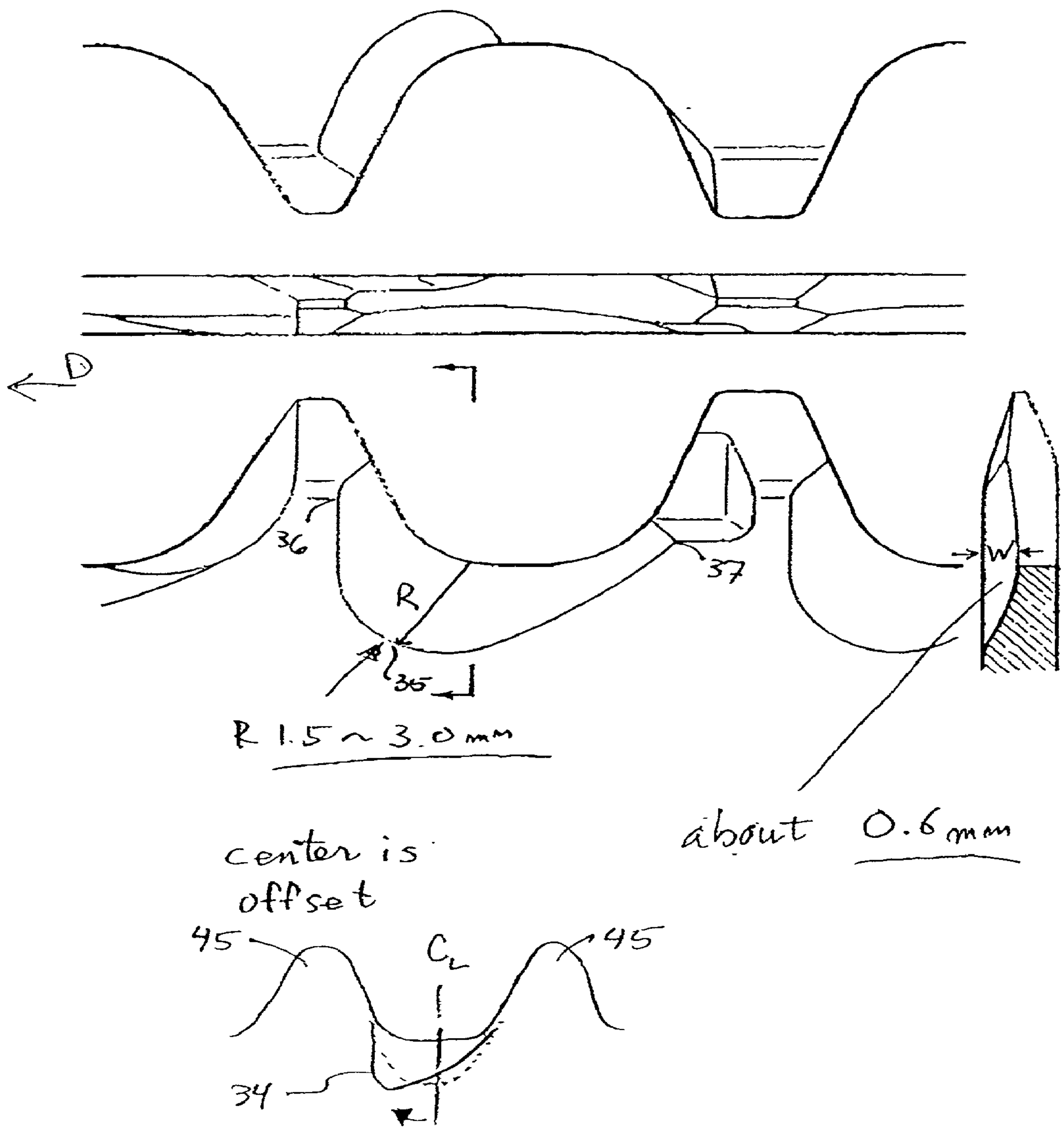
Front view of chain ring
46 Teeth.

FIG. 3



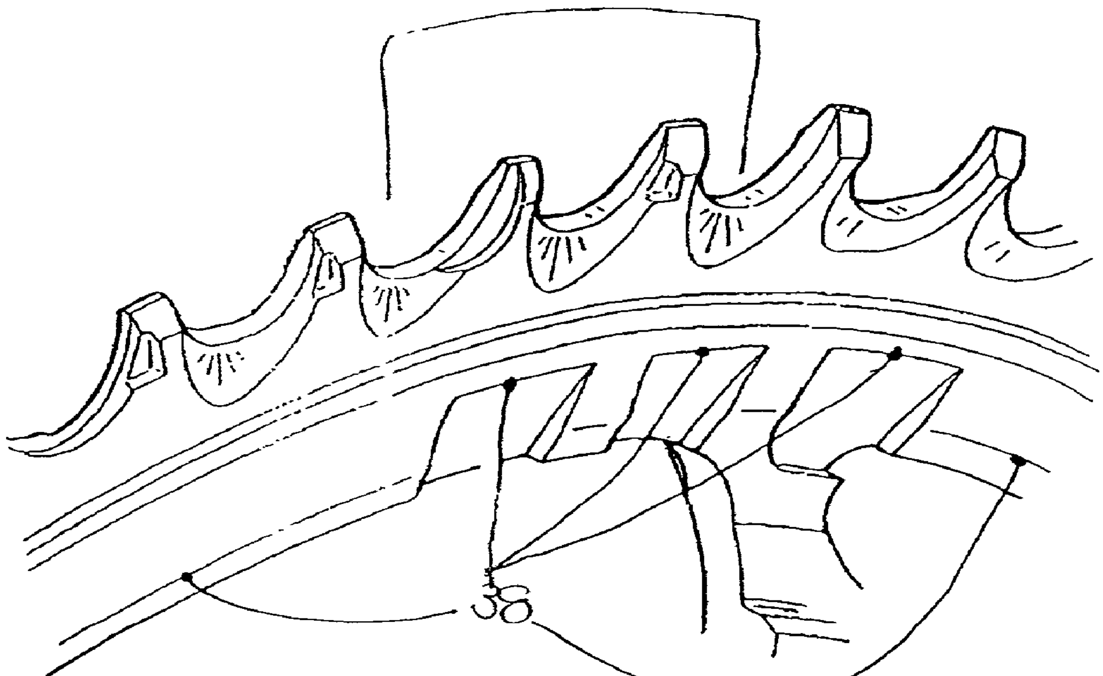
back view of chain ring

FIG. 4



48 Teeth

FIG. 5



New champer

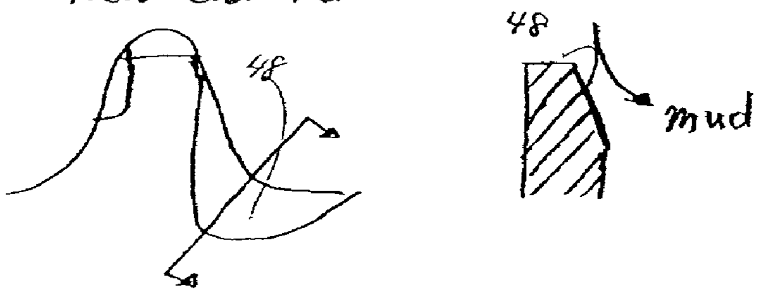


FIG. 6

old recess

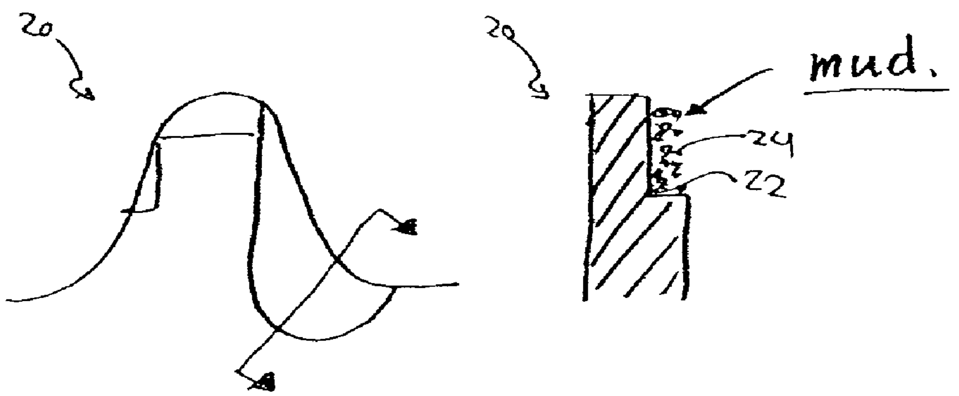
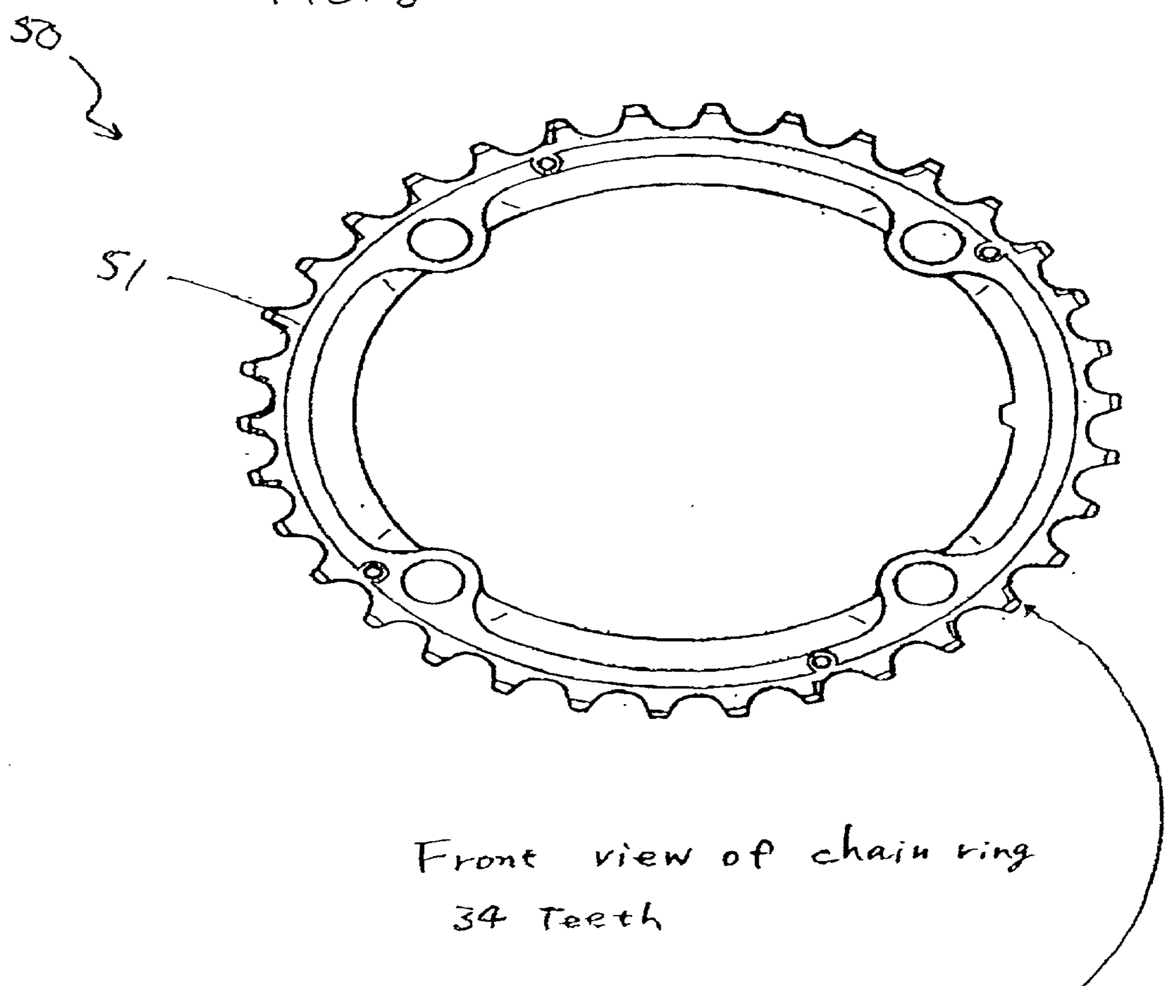


FIG. 7

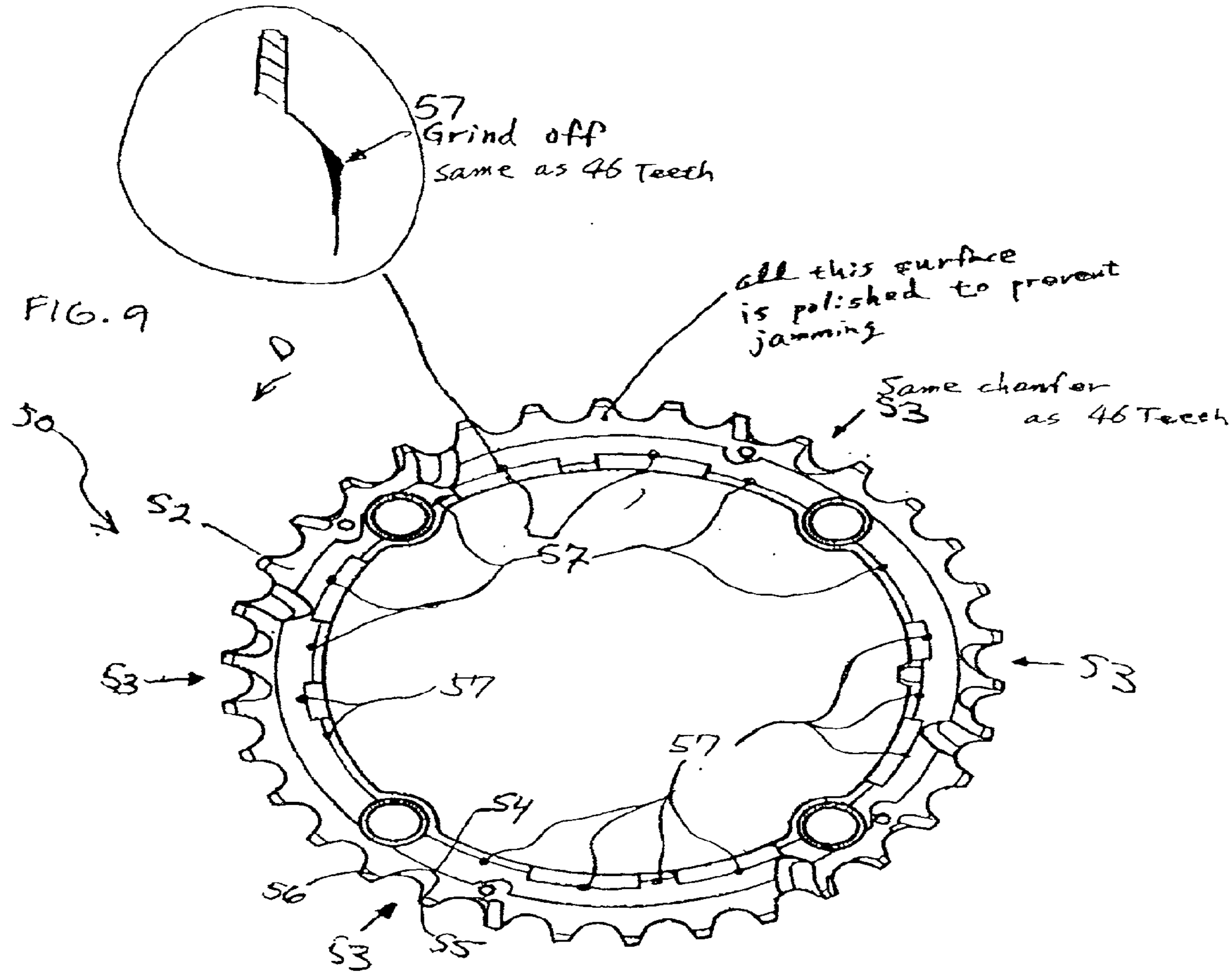
FIG. 8



Front view of chain ring
34 Teeth

Some teeth have small step.

FIG. 9



Back view of chainwheel
34 Teeth

FIG. 10

FRONT VIEW OF CHAIN WHEEL

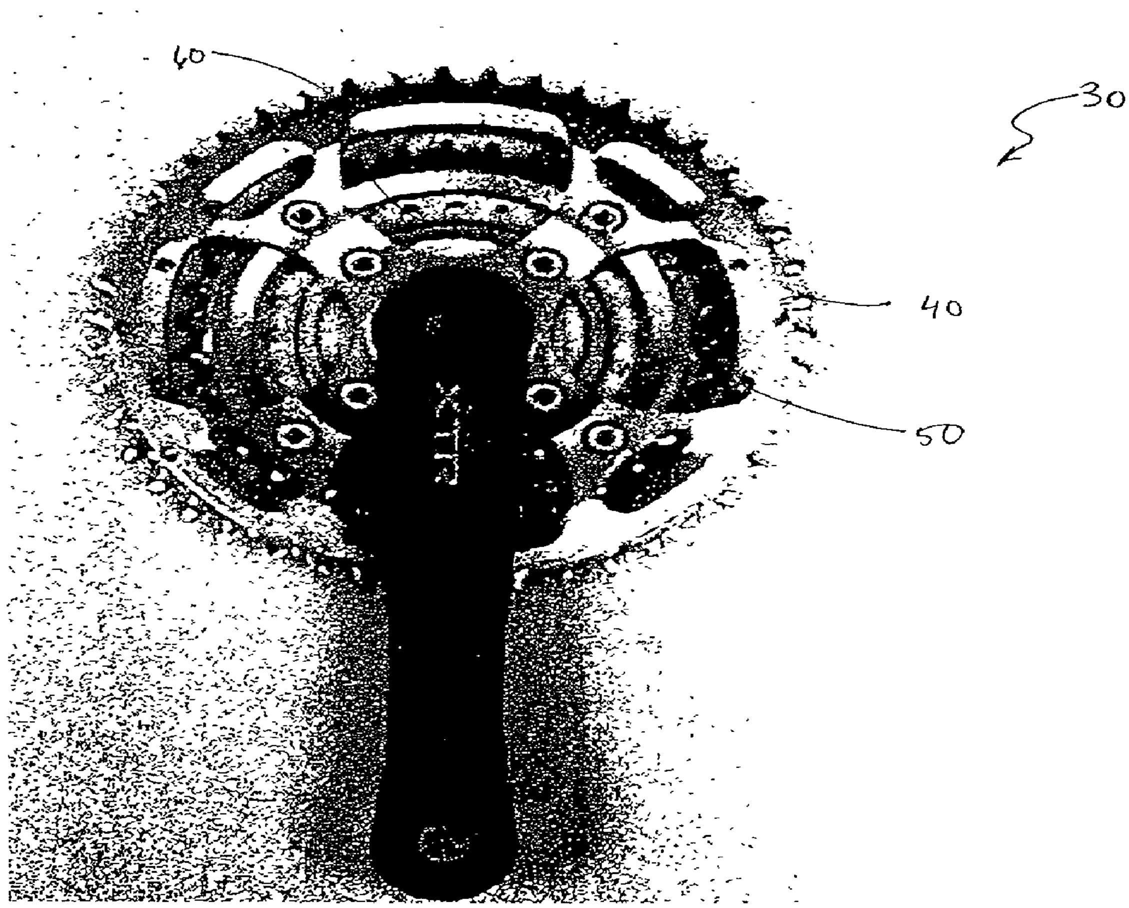
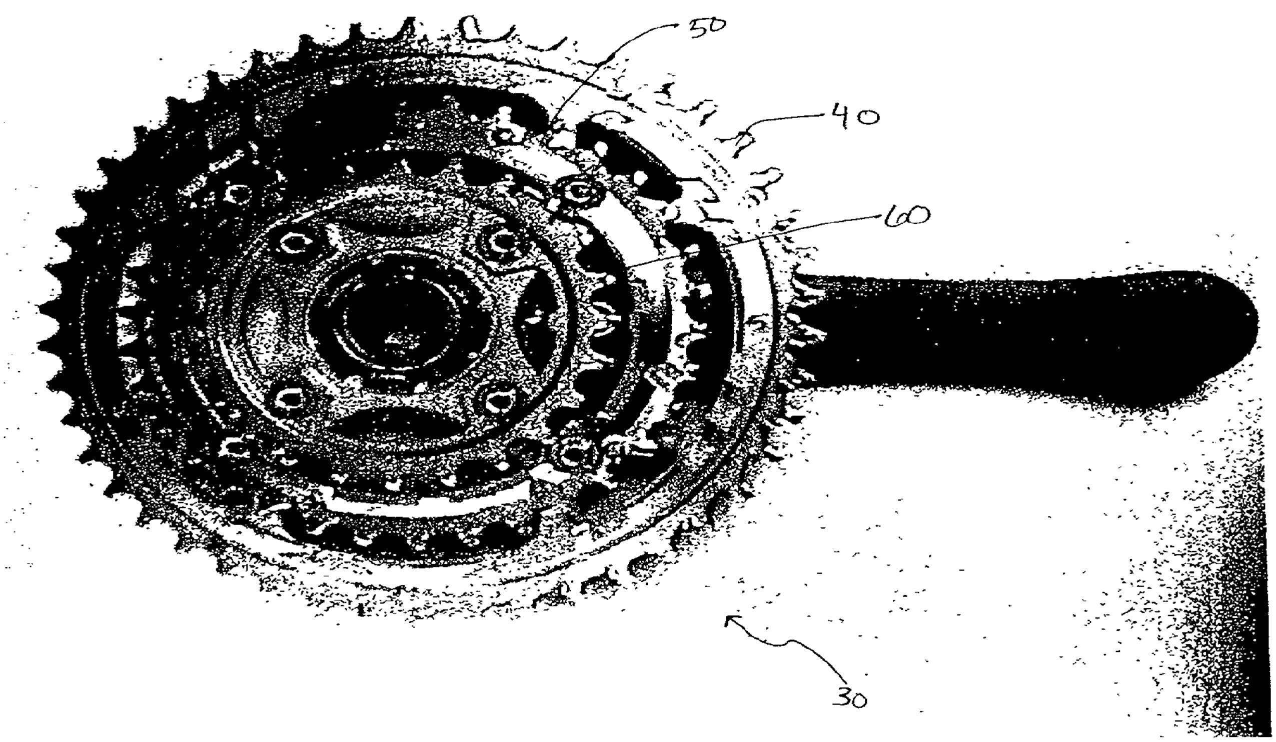


FIG. 11

BACK VIEW OF CHAINWHEEL
46T - 34T - 24T



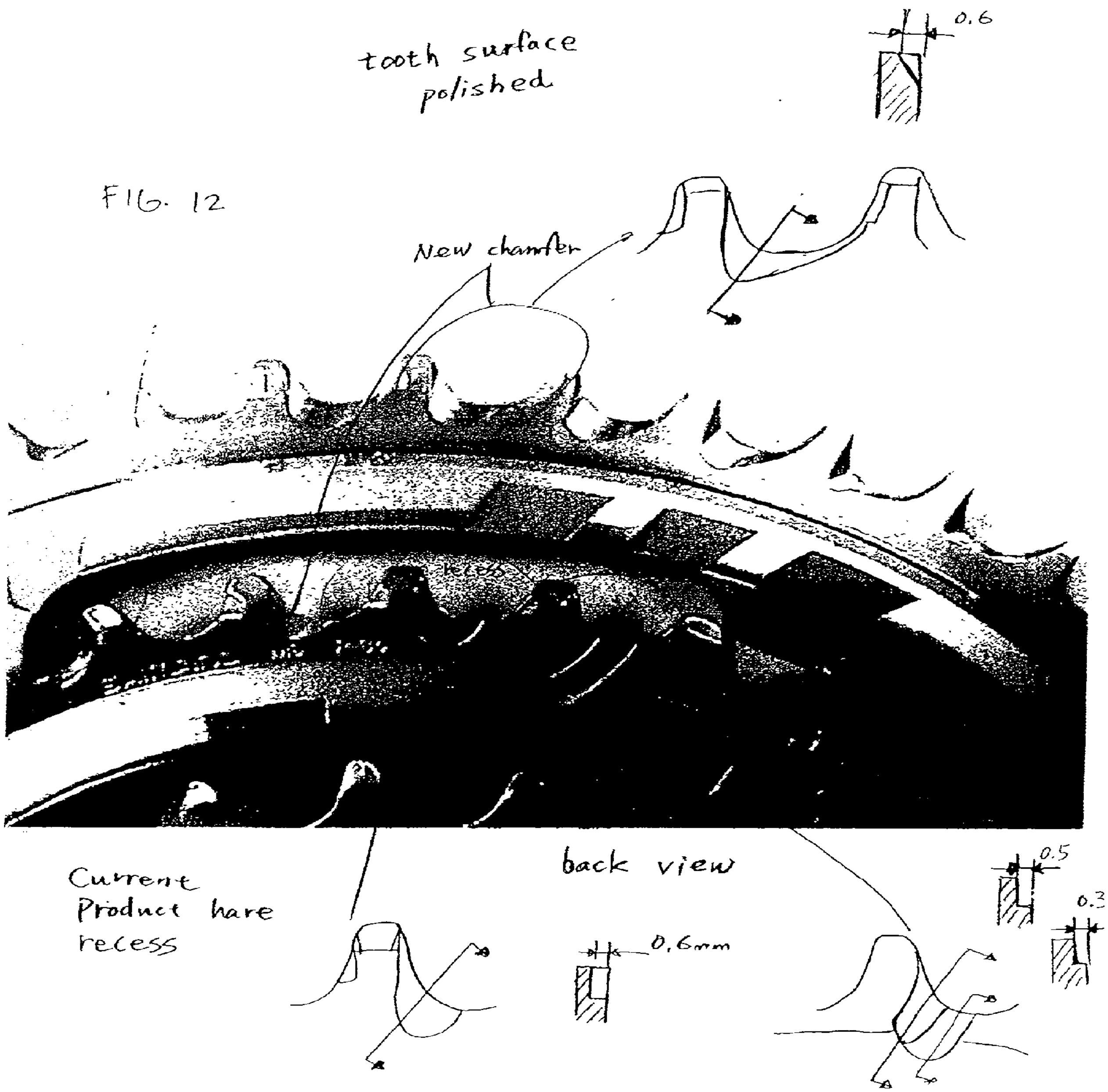

tooth surface polished
0.6
New chamfer
Current Product hare recess
back view
0.6mm
0.5
0.3

FIG. 12

FIG. 13

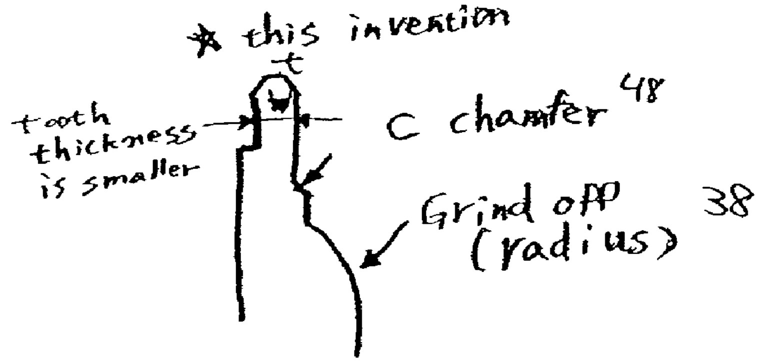

this invention
t
tooth thickness is smaller
C chamfer 48
Grind off (radius) 38

FIG. 14

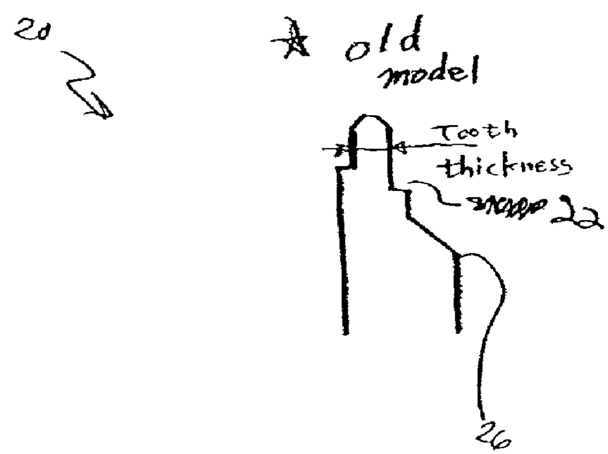

20
old model
Tooth thickness
22
26

FIG. 15a

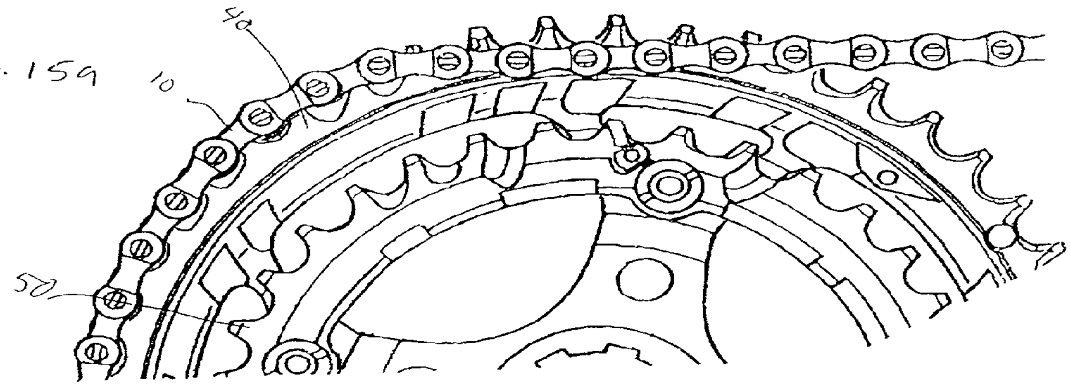


FIG. 15b

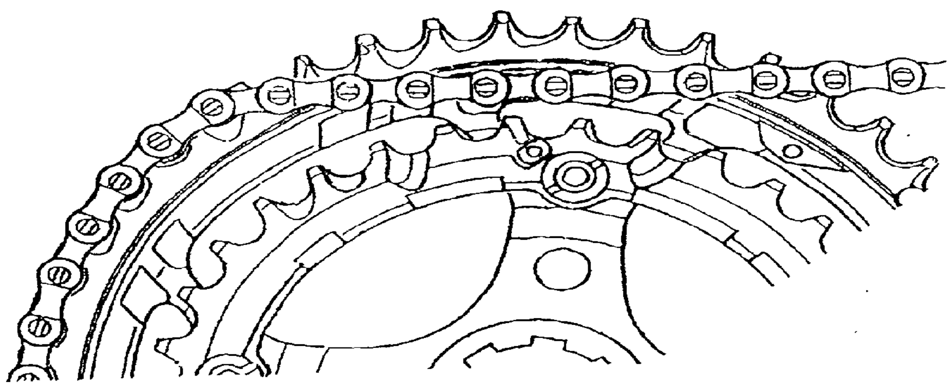


FIG. 15c

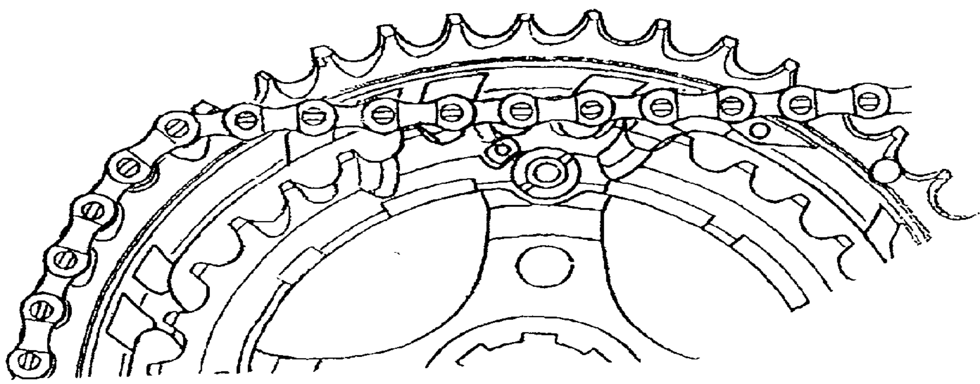


FIG. 16a

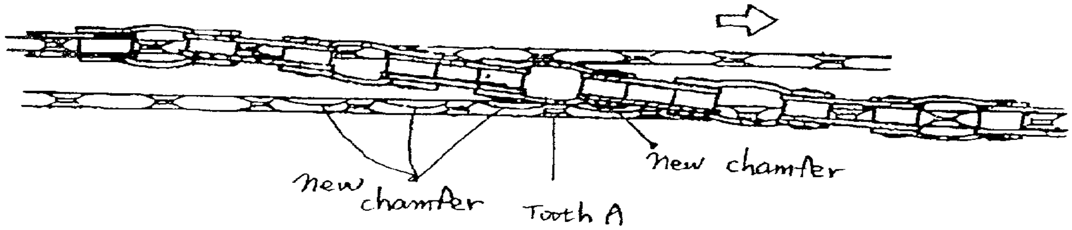


FIG. 16b

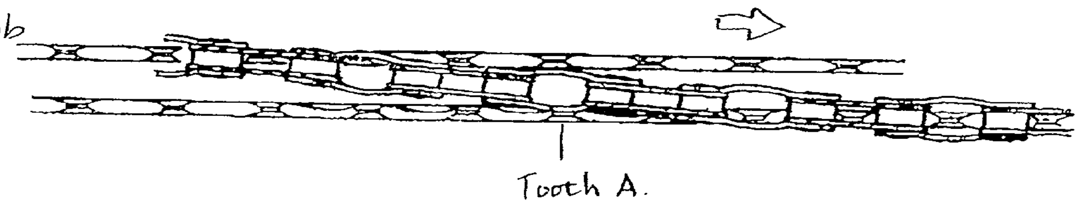


FIG. 16c

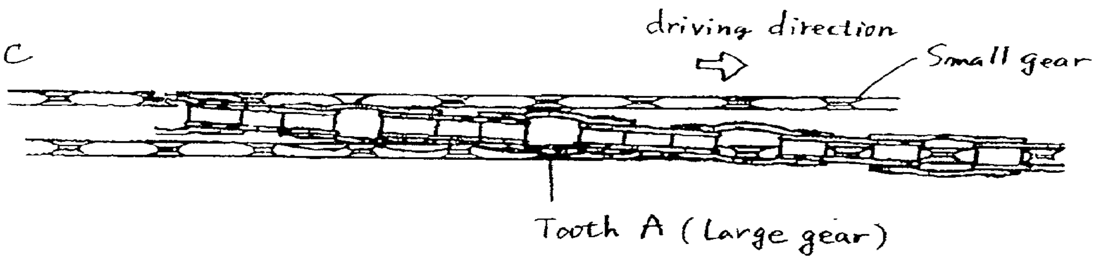
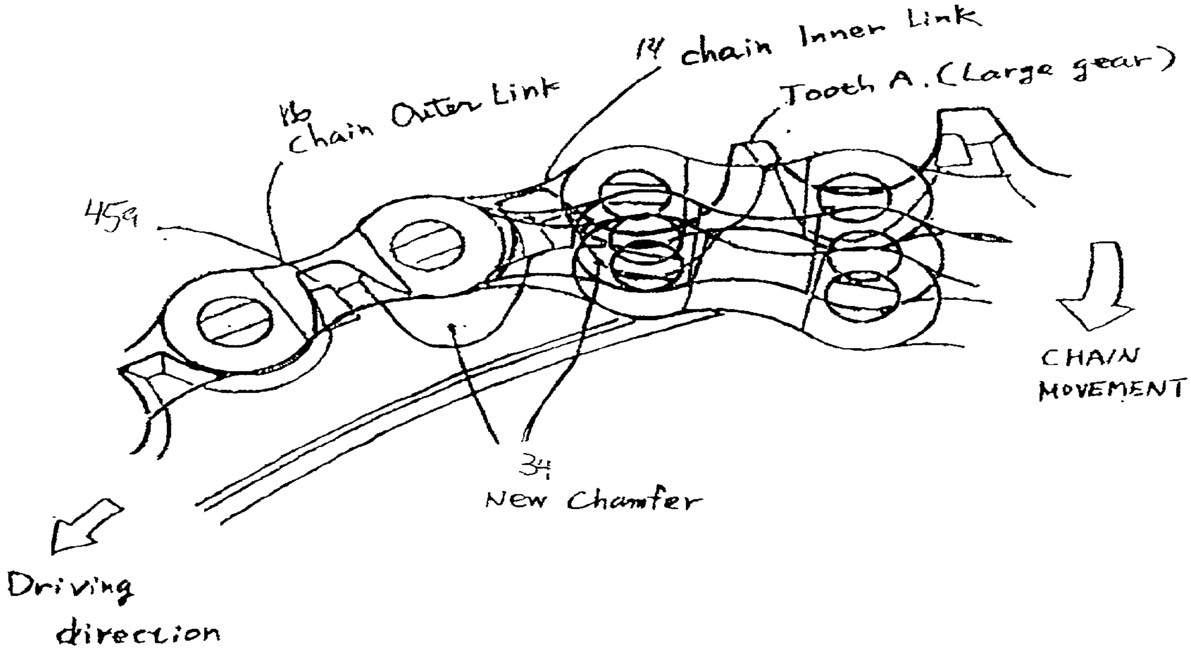


FIG. 17


14 chain Inner Link
Tooth A. (Large gear)
16 Chain Outer Link
45a
CHAIN MOVEMENT
34
New Chamfer
Driving direction

CHAMFERED SPROCKET ASSEMBLY

FIELD OF THE INVENTION

[0001] The present invention relates to a multi-stage sprocket assembly for a bicycle and more particularly to a multi-stage sprocket assembly having chamfered sprockets configured to facilitate the shifting of a drive chain from a larger sprocket to a smaller sprocket.

BACKGROUND OF THE INVENTION

[0002] According to a conventional multi-sprocket assembly, the large sprocket of the assembly includes a disengagement-facilitating means for facilitating disengagement of the drive chain from teeth of the large sprocket when the drive chain is shifted from the large sprocket to the small sprocket to change a driving speed of the bicycle. Specifically, the disengagement means comprises reduction in the height of some of the teeth of the large sprocket relative to the other teeth in order to facilitate the chain disengagement at the specified portion of the large sprocket.

[0003] Various features have been added to the traditional multi-sprocket assembly to ensure smooth and reliable chain shift action from the large sprocket to the small sprocket. For example, according to a conventional multi-stage sprocket assembly, the large sprocket has, in its face facing the small sprocket, a concavity to form a stepped portion for receiving the shifting drive chain when the chain is shifted from the large sprocket to the small sprocket disposed adjacent thereto. Specifically, the stepped portion is provided at a position higher than the dedendum of the teeth of the large sprocket so as to avoid locking of the shifting chain segment to the large sprocket.

[0004] The problems with the chain shift action is exacerbated by environmental conditions, such as mud and dirt, which can collect in the drive chain links and in the stepped portions of the sprocket assembly. **FIG. 1***a* depicts a typical drive chain **10** having a plurality of links **12**, wherein each link includes an inner portion **14** and an outer portion **16**. As shown in **FIG. 1***b*, when a typical new, clean drive chain **10** is bent, the drive chain has a bending arc **18** of approximately 300 mm. However, when there is shifting in mud or dirt, particles gather in the links of the drive chain. As a result of the fine mud and dirt particles settling into the links **12** of the drive chain **10**, the drive chain becomes stiff and the bending arc **18** decreases in height. **FIG. 1***c* depicts a drive chain that has been stiffened due to the settling of mud and dirt particles in the links **12** of the drive chain **10**. As shown in **FIG. 1***c*, the bending arc **18**' has decreased to 100 mm, significantly less than the bending arc **18** of a new, clean drive chain. When the drive chain is in a stiffened condition, the occurrence of chain jamming incidents significantly increases.

[0005] Accordingly, it is desirable to provide a multi-stage sprocket assembly for a bicycle that offers smooth and reliable chain shift action from the large sprocket to the small sprocket even in inclement conditions, such as mud or dirt.

SUMMARY OF THE PREFERRED EMBODIMENTS

[0006] The present invention overcomes the disadvantages of the prior art. A chamfered sprocket assembly for facilitating the shifting of a drive chain from a larger sprocket to a smaller sprocket is disclosed. In a preferred embodiment of the invention, the chamfered sprocket assembly includes a sprocket having a plurality of chamfered portions on a side face facing a smaller sprocket, each chamfered portion located between a pair of toothlike projections located on the rim of the sprocket body. Each of the chamfered portions preferably include a crest which tapers toward a first edge and a second edge of the chamfer portion, respectively. The crest is preferably offset from the center of the chamfer portion toward the driving direction of the sprocket assembly. If there are more than two sprockets in the sprocket assembly, the intermediate sprockets also have chamfered portions to facilitate the smooth transition of the drive chain from one sprocket to another.

[0007] To further facilitate the shifting of the drive chain, the sprocket preferably includes a rounded shoulder to guide the movement of the drive chain. Finally, the friction between the toothlike projections and the drive chain is reduced by polishing the toothlike projections.

[0008] Other objects, features and advantages of the present invention will become apparent to those skilled in the art from the following detailed description. It is to be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the present invention, are given by way of illustration and not limitation. Many changes and modifications within the scope of the present invention may be made without departing from the spirit thereof, and the invention includes all such modifications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The invention may be more readily understood by referring to the accompanying drawings in which:

[0010] **FIG. 1***a* is a typical drive chain used with a sprocket assembly;

[0011] **FIG. 1***b* depicts the arc bend of a typical, clean drive chain used with a sprocket assembly;

[0012] **FIG. 1***c* depicts te arc bend of a typical drive chain that has been stiffened by the accumulation of mud and dirt particles in the links of the drive chain;

[0013] **FIG. 2** is a front view of a preferred embodiment of the large sprocket of the present invention having small chamfered portions between the teeth;

[0014] **FIG. 3** is a back view of a preferred embodiment of the large sprocket of the present invention having large chamfered portions;

[0015] **FIG. 4** depicts various views of the large chamfered portion of a preferred embodiment of the sprocket of the present invention;

[0016] **FIG. 5** is a perspective view of a portion of a preferred embodiment of the sprocket of the present invention having chamfered portions;

[0017] **FIG. 6** is cross-sectional view of the chamfered portion of a preferred embodiment of the present invention;

[0018] **FIG. 7** is a cross-sectional view of a stepped portion of a known sprocket assembly;

[0019] **FIG. 8** is a front view of a preferred embodiment of another sprocket of the present invention;

[0020] **FIG. 9** is a back view of a preferred embodiment of another sprocket of the present invention;

[0021] **FIG. 10** is a front view of a preferred embodiment of a chainwheel of the present invention;

[0022] **FIG. 11** is a back view of a preferred embodiment of a chainwheel of the present invention;

[0023] **FIG. 12** is a partial view of a preferred embodiment of a chainwheel of the present invention depicting chamfered portions on the larger and smaller sprockets;

[0024] **FIG. 13** is a cross-sectional view of a preferred embodiment of the sprocket of the present invention having a chamfered portion and continuous shoulder;

[0025] **FIG. 14** is a cross-section view of a known sprocket having a stepped portion and a sharp-edged shoulder;

[0026] **FIGS. 15**_a-c_ is a back view of the progressive shifting of the drive chain from a larger sprocket to a smaller sprocket of a preferred embodiment of the present invention;

[0027] **FIGS. 16**_a-c_ is a top view of the progressive shifting of the drive chain from a larger sprocket to a smaller sprocket of a preferred embodiment of the present invention; and

[0028] **FIG. 17** is an enlarged view of the chain and sprocket assembly depicting the motion of the drive chain.

[0029] Like numerals refer to like parts throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] Preferred embodiments of a chamfered sprocket assembly for a bicycle relating to the present invention will now be described in particular with reference to the accompanying drawings.

[0031] As shown in **FIGS. 10 and 11**, in a preferred embodiment of the present invention, the bicycle chainwheel **30** includes a larger sprocket **40**, a smaller sprocket **50** and a smallest sprocket **60**. The sprockets are preferably arranged such that the smaller sprocket **50** is positioned between the larger sprocket **40** and smallest sprocket **60**. The sprockets **40**, **50**, **60** are configured and arranged to facilitate the shifting of a drive chain (not shown) from one sprocket to another during the gear shifting of a bicycle. The chainwheel may be configured with fewer or additional sprockets without departing from the inventive concepts disclosed herein. For example, in one embodiment of the invention, the chainwheel includes a larger sprocket and the smallest sprocket, eliminating the intermediate "smaller" sprocket. In a preferred embodiment of the invention, the larger sprocket **40** has forty-six **(46)** toothlike projections, the smaller sprocket has thirty-four **(34)** toothlike projections, and the smallest sprocket has twenty-four **(24)** toothlike projections. The number of toothlike projections on each sprocket may vary without departing from the inventive concept disclosed herein. The toothlike projections of the sprockets are phase-arranged to facilitate the smooth movement of the drive chain from one sprocket to another.

[0032] **FIGS. 2 through 6** depict a preferred embodiment of the larger sprocket **40** of the present invention. As shown in **FIG. 2**, the front side **41** of the larger sprocket includes a sprocket body **42**, having a center **43**, and sprocket rim **44** around the periphery thereof. A plurality of toothlike projections **45** are arranged on the rim **44** of the body **42** and configured to engage the drive chain (not shown). The region between each pair of toothlike projections **45** is preferably beveled, defining a chamfered portion **46**. The chamfered portion **46** preferably extends from the rim **44** of the sprocket body **42** toward the center **43** of the sprocket body **42**. In a preferred embodiment of the invention, the larger sprocket **40** includes a chamfered portion **46** between each pair of toothlike projections **45** on the front side **41** of the larger sprocket **40**.

[0033] As shown in **FIG. 3**, the back side **31** of the larger sprocket **40** includes a first and second disengagement-facilitating portions **32, 33** for facilitating the disengagement of a drive chain at this predetermined portion when the chain is shifted from the larger sprocket **40** to the smaller sprocket **50**. The disengagement-facilitating portions are provided at two peripheral positions of the larger sprocket **40** with 180 degree displacement therebetween. The disengagement-facilitating portions are chosen to provide an optimal location for a chain shift because bicycle-driving torque applied to the crank device is minimum at that position.

[0034] To facilitate the disengagement of the chain from the larger sprocket **40** and the shift of the drive chain to the smaller sprocket **50**, one or more of the toothlike projections **45** in the disengagement-facilitating portions **32, 33** have a shorter tooth height than all of the other toothlike projections of the larger sprocket **40**. In a more preferred embodiment, the disengagement-facilitating portions **32, 33** include a plurality of teeth, each having a progressively shorter tooth height than the adjacent tooth.

[0035] To further facilitate the disengagement of the drive chain from the larger sprocket **40** and to the smaller sprocket **50**, the back side **31** of the larger sprocket **40** preferably includes chamfered portions **34** between each pair of toothlike projections **45** within the disengagement-facilitating portions **32, 33**. The chamfered portions **34** on the back side **31** of the larger sprocket **40** are preferably larger than the chamfered portions **46** on the front side **41** of the larger sprocket **40**. In a more preferred embodiment of the present invention, the back side **31** of the larger sprocket **40** also includes smaller chamfered portions **46** outside of the disengagement-facilitating portions **32, 33**. Accordingly, smaller chamfered portions **46** are provided on the back side **31** of the larger sprocket **40** between each pair of toothlike projection on the rim, other than the disengagement-facilitating portions **32, 33** of the sprocket **40**.

[0036] In the disengagement-facilitating portions **32, 33**, each of the chamfered portions **34** on the back side **31** of the larger sprocket **40** includes a crest **35**, a first edge **36** and a second edge **37** and each of the chamfered portions **34** preferably tapers from the crest **35** toward each of the first edge **36** and the second edge **37**, respectively.

[0037] As best shown in **FIG. 4**, the crest **35** of the chamfered portion **34** is preferably offset from the center line C_L of the chamfered portion **34** toward the driving direction D of the larger sprocket **40**. In a preferred embodiment of the invention, the radius of curvature, R, of the crest **35** of the

chamfered portion **34** measures in the range of about 1.5 mm to 3.0 mm and the width, W, of the chamfered portion **34** measures about 0.6 mm.

[**0038**] **FIGS. 6 and 7** illustrate one of the differences between known sprockets and the present invention. As shown in **FIG. 7, a** known sprocket **20** includes a stepped portion **22** configured to receive the drive chain and facilitate the shift of the drive chain from one sprocket to another. A disadvantage of the known sprocket design is that mud and dirt particles **24** can accumulate in the stepped portion **22**, thus interfering with the shifting of the drive chain. As shown in **FIG. 6**, the present invention overcomes the disadvantage of the known sprocket **20** by providing a chamfered portion **48** that does not accumulate mud or dirt particles. The chamfered portion **48** is preferably continuous and does not include sharp edges that are conducive to accumulating unwanted particles. The configuration of the chamfered portion **48** allows any dirt or mud particles to slide off of the sprocket, keeping the sprocket, the toothlike projections, and ultimately, the drive chain free of mud and dirt particles.

[**0039**] To further facilitate the movement of the drive chain from the larger sprocket **40** to the smaller sprocket **50**, the larger sprocket **40** includes a shoulder **38** on the back side **31** of the larger sprocket **40**. The shoulder **38** is preferably smoothened to create a continuously rounded shoulder, such that no sharp edges exist. In a preferred embodiment of the invention, the shoulder **38** can be smoothened by grinding off the surface of the back side of the larger sprocket to create a rounded shoulder.

[**0040**] In a preferred embodiment of the invention, the drive chain is shifted from the larger sprocket **40** to the smaller sprocket **50** to the smallest sprocket **60**. The sprockets are preferably arranged such that the back side of the larger sprocket **40** faces the front side of the smaller sprocket **50**, and the back side of the smaller sprocket **50** faces the front side of the smallest sprocket **60**. **FIGS. 8 and 9** depict the front and back side, respectively, of the smaller sprocket **50**. As shown in **FIG. 8**, the front side **51** of the smaller sprocket preferably does not include any chamfered portions like the chamfered portions on the large sprockets. As shown in **FIG. 9**, the back side **52** of the smaller sprocket **50** includes a plurality of chamfered portions **53** configured to facilitate the shifting of the drive chain from the smaller sprocket **50** to the smallest sprocket **60**. The chamfered portions **53** on the back side **52** of the smaller sprocket **50** are preferably identical to the chamfered portions **34** on the back side **31** of the larger sprocket **40**. Namely, each of the chamfered portions **53** on the back side **52** of the smaller sprocket **50** includes a crest **54**, a first edge **55** and a second edge **56**. Each of the chamfered portions **53** preferably tapers from the crest **54** toward each of the first edge **55** and the second edge **56**, respectively. Furthermore, the crest **54** of the chamfered portion **53** is preferably offset from the center line of the chamfered portion **53** toward the driving direction D of the smaller sprocket **50**.

[**0041**] To further facilitate the disengagement of the drive chain from the smaller sprocket **50** and the movement of the drive chain to the smallest sprocket **60**, the smaller sprocket **50** includes a shoulder **57** on the back side **52** of the smaller sprocket **50**, facing the smallest sprocket **60**. The shoulder **57** is preferably smoothened to create a continuously rounded shoulder, such that no sharp edges exist. In a preferred embodiment of the invention, the shoulder **57** can be smoothened by grinding off the surface of the back side of the larger sprocket to create a rounded shoulder.

[**0042**] **FIG. 12** shows the back side of the larger sprocket **40**, the smaller sprocket **50** and the smallest sprocket **60**. As shown in **FIG. 12**, the larger sprocket **40** and smaller sprocket **50** include chamfered portions for facilitating the disengagement of the drive chain and the movement of the chain from the larger sprocket **40** to the smaller sprocket **50**, and from the smaller sprocket **50** to the smallest sprocket **60**.

[**0043**] **FIGS. 13 and 14** illustrates some of the differences between the known sprockets **20** and the sprockets of the present invention. As shown in **FIG. 14, a** known sprocket includes a stepped portion **22** and a sharp-edged shoulder **26**. In contrast, as shown in **FIG. 13**, the sprocket of the present invention provides a chamfered portion **48** that does not accumulate mud or dirt particles and a smooth, continuous shoulder **38** that facilitates the movement of the drive chain from one sprocket to another. In a preferred embodiment of the invention, the toothlike projections have a thickness, t, of about 1.8 mm, which is smaller than the thickness of the known sprocket teeth.

[**0044**] **FIGS. 15 through 17** illustrate the disengagement of the drive chain **10** from the larger sprocket **40** and the movement of the drive chain from a larger sprocket **40** to the smaller sprocket **50**. The function of the chamfered portions **34**, **48** in the course of a change-speed shifting operation of the drive chain **10** will be particularly described. The drive chain **10** employed in this particular embodiment, is a roller chain consisting of two kinds of link plates, i.e. inner plates **14** and outer plates **16** pivotably and alternately connected to each other.

[**0045**] With reference to **FIGS. 15***a***-15***c* and **16***a***-16***c*, with a rider's operation of an unillustrated derailleur, the drive chain **10** currently engaging the larger sprocket **40** is laterally displaced toward the smaller sprocket **50**. The chamfered portions **34**, **48** of the larger sprocket **40** and the smaller sprocket **50** facilitate the motion of the drive chain **10** by not accumulating dirt or mud thereon and by guiding the motion of the drive chain **10** toward the adjacent sprocket.

[**0046**] As best shown in **FIG. 17**, the outer plate **16** of the drive chain **10** rides over the first tooth **45***a* and the subsequent inner plate **14** moves toward the smaller sprocket **50**. In this condition, the chain **10** is laterally flexed and with further rotation of chainwheel **30**, the chain **10** moves in a downward direction. The chamfered portions **34** guide the motion of the chain **10** and ensure a smooth transition to the smaller sprocket **50**.

[**0047**] In a preferred embodiment of the invention, to further improve the motion of the chain **10** from one sprocket to another, the toothlike projections on the sprockets are polished. The polishing is preferably accomplished using a buffing material and a polishing paste. The toothlike projections on the sprockets are preferably polished on the until any machining grooves on the surface of the tooth disappears. by polishing the tooth surface, the friction on the toothlike projection and the drive chain is reduced.

[**0048**] There has been described hereinabove an exemplary embodiment of a chamfered sprocket assembly

according to the principles of the present invention. Those skilled in the art may now make numerous uses of, and departures from, the above-described embodiment without departing from the inventive concepts disclosed herein. Accordingly, the present invention is to be defined solely by the scope of the following claims.

What is claimed is:

1. A sprocket for engagement with a chain, the sprocket comprising:

a sprocket body having a center, a first side, and a rim on the outside periphery thereof;

a plurality of toothlike projections arranged on the rim of the sprocket body to engage the chain; and

wherein the first side of the sprocket body includes a chamfer portion between the toothlike projections, the chamfer portion extending from the rim in a direction toward the center of the sprocket body.

2. A sprocket in accordance with claim 1 wherein the chamfer portion includes a crest, a first edge and a second edge, and wherein the chamfer portion tapers from the crest to the first edge and the second edge, respectively.

3. A sprocket in accordance with claim 2 wherein the chamfer portion is asymmetrical.

4. A sprocket in accordance with claim 2 wherein the crest is offset from a center of the chamfer portion.

5. A sprocket in accordance with claim 4 wherein the sprocket has a driving direction and the crest of the chamfer is offset towards the driving direction.

6. A sprocket in accordance with claim 5 wherein the chamfer portion has a radius of curvature at the crest in the range of 1.5 to 3.0 millimeters.

7. A sprocket in accordance with claim 1 further comprising a shoulder on the sprocket body, wherein the shoulder is rounded.

8. A sprocket in accordance with claim 1 further comprising a second side having a plurality of chamfer portions, each chamfer portion adjacent one of the toothlike projections.

9. A sprocket in accordance with claim 8 wherein the chamfer portions on the second side of the sprocket body are smaller than the chamfer portions on the first side of the sprocket body.

10. A sprocket in accordance with claim 1 wherein the tooth-like projections are polished.

11. A chainwheel assembly comprising:

a large sprocket having a sprocket body with a center, a first side, and a rim on the outside periphery thereof, a plurality of toothlike projections arranged on the rim of the sprocket body to engage the chain, wherein the first side of the sprocket body includes a chamfer portion between the toothlike projections, the chamfer portion extending from the rim in a direction toward the center of the sprocket body; and

a smaller sprocket having a first side and a second side, wherein the second side of the smaller sprocket faces the first side of the larger sprocket and the first side of the smaller sprocket faces away from the first side of the larger sprocket.

12. A chainwheel assembly in accordance with claim 11 wherein the smaller sprocket includes a sprocket body with a center, a first side, and a rim on the outside periphery thereof, a plurality of toothlike projections arranged on the rim of the sprocket body to engage the chain, wherein the first side of the sprocket body includes a chamfer portion between the toothlike projections, the chamfer portion extending from the rim in a direction toward the center of the sprocket body.

13. A chainwheel assembly in accordance with claim 12 wherein each of the chamfer portion of the larger sprocket and the smaller sprocket includes a crest, a first edge and a second edge, and wherein each of the chamfer portions tapers from the crest to the first edge and the second edge, respectively.

14. A chainwheel assembly in accordance with claim 13 wherein each of the chamfer portions is asymmetrical.

15. A chainwheel assembly in accordance with claim 13 wherein the crest of each of the chamfer portions is offset from a center of the chamfer portion.

16. A chainwheel assembly in accordance with claim 15 wherein each of the larger and the smaller sprockets has a driving direction and the crest of the chamfer portion of each of the sprockets is offset towards the driving direction.

17. A chainwheel assembly in accordance with claim 16 wherein each of the chamfer portions has a radius of curvature at the crest in the range of 1.5 to 3.0 millimeters.

18. A chainwheel assembly in accordance with claim 11 further comprising a shoulder on the sprocket body, wherein the shoulder is rounded.

19. A chainwheel assembly in accordance with claim 12 further comprising a shoulder on the sprocket body of the smaller sprocket, wherein the shoulder is rounded.

20. A chainwheel assembly in accordance with claim 11 further comprising a second side having a plurality of chamfer portions, each chamfer portion adjacent one of the toothlike projections.

21. A chainwheel assembly in accordance with claim 20 wherein each of the chamfer portions on the second side of the sprocket body are smaller than the chamfer portions on the first side of the sprocket body.

22. A chainwheel assembly in accordance with claim 11 wherein the tooth-like projections are polished.

23. A sprocket for engagement with a chain, the sprocket comprising:

a sprocket body having a center, a first side, and a rim on the outside periphery thereof;

a plurality of toothlike projections arranged on the rim of the sprocket body to engage the chain;

a plurality of chamfered portions, each chamfered portion located between one of the toothlike projections and an adjacent toothlike projection;

a disengagement-facilitating portion of the sprocket including at least one of the plurality of toothlike projections and at least one of the chamfered portions;

wherein the chamfered portions outside of the disengagement-facilitating portion are smaller than the chamfered portions within the disengagement-facilitating portion.

* * * * *

United States Patent [19]

Nagano

[11] **Patent Number: 4,889,521**

[45] **Date of Patent: Dec. 26, 1989**

[54] **MULTISTAGE SPROCKET ASSEMBLY FOR A BICYCLE**

[75] Inventor: Masashi Nagano, Izumi, Japan

[73] Assignee: **Shimano Industrial Company Limited,** Osaka, Japan

[21] Appl. No.: **261,323**

[22] Filed: **Oct. 24, 1988**

[30] **Foreign Application Priority Data**

Oct. 21, 1987 [JP] Japan 62-161539
Jun. 4, 1988 [JP] Japan 63-74583

[51] **Int. Cl.**^{4} **F16H 11/08**
[52] **U.S. Cl.** **474/164**
[58] **Field of Search** .... 474/160, 162, 164, 152, 474/155–157; 74/594.2; 29/159 R

[56] **References Cited**

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Primary Examiner—Thuy M. Bui

Attorney, Agent, or Firm—Stevens, Davis, Miller & Mosher

[57] **ABSTRACT**

A multistage sprocket assembly is provided which includes at least one larger diameter sprocket and at least one smaller diameter sprocket assembled in a relationship such that the center point between a pair of adjacent teeth at the larger diameter sprocket and the center point between a pair of adjacent teeth at the smaller diameter sprocket are positioned on a tangent extending along the chain path when the chain is being shifted from the smaller diameter sprocket to the larger diameter sprocket. The distance between both the center points is equal to an integer multiple of the chain pitch. A chain guide portion is provided at the inside surface of the larger diameter sprocket and at a position corresponding to a moving path of a driving chain traveling between the aforesaid center points for allowing the chain to move axially of the sprocket assembly slightly toward the larger diameter sprocket during shifting.

6 Claims, 4 Drawing Sheets

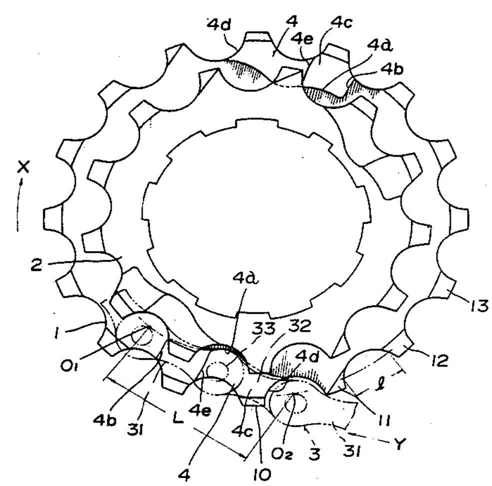


Fig. 1

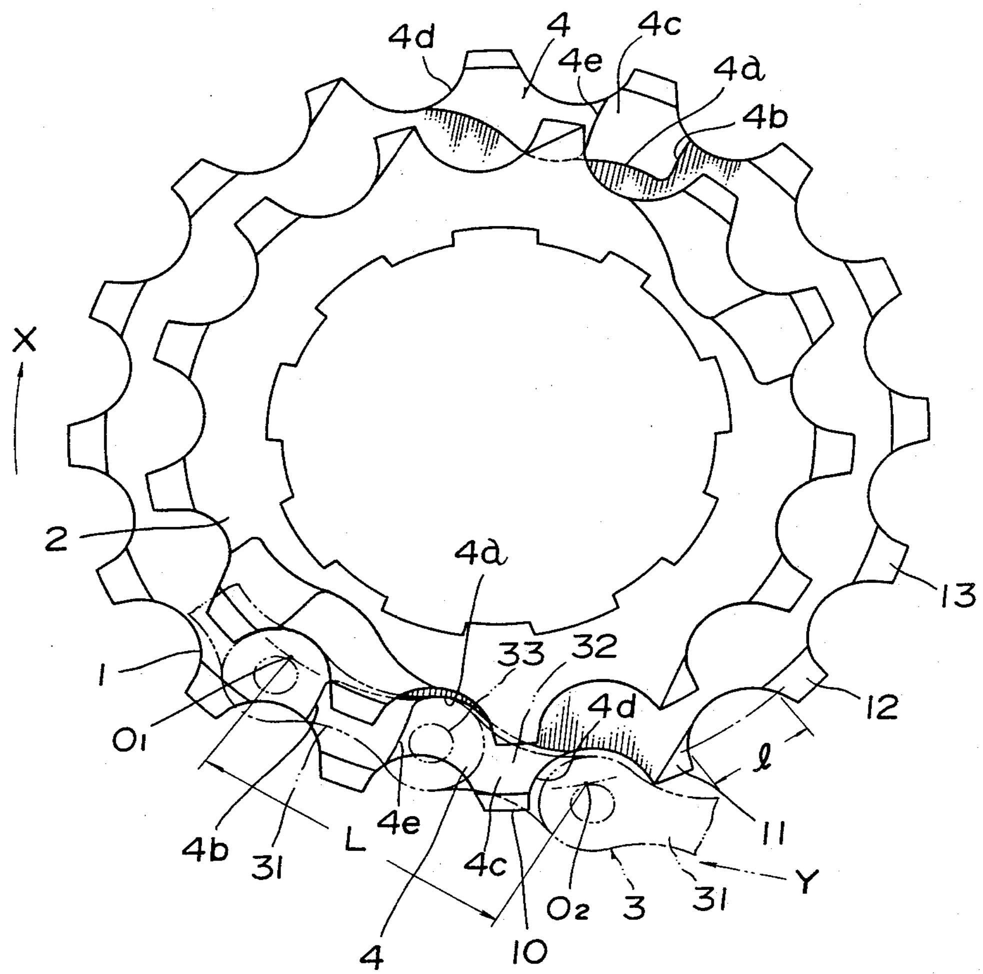


Fig. 2

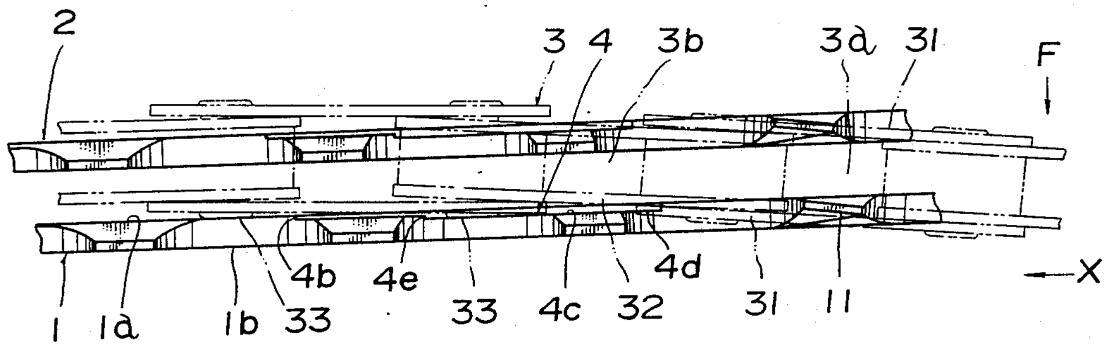

2
3
4
3b
3a
31
F
X
1
1a
1b
33
4b
4e
33
4c
32
4d
31
11

Fig. 3

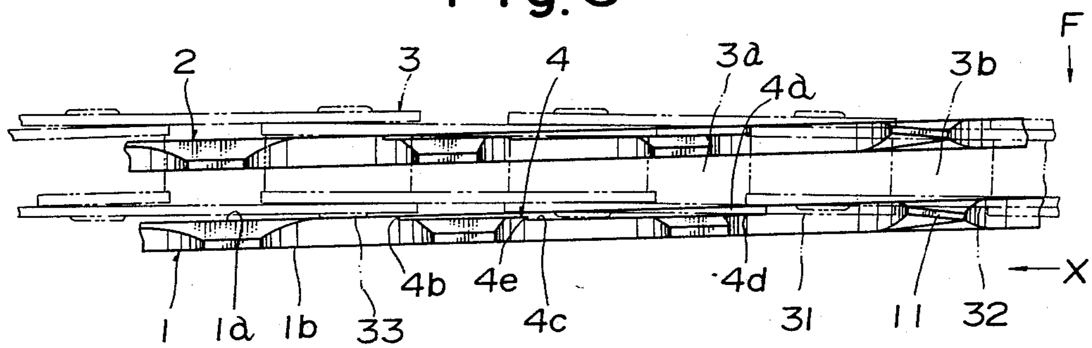

F
2
3
4
3a
4a
3b
X
1
1a
1b
33
4b
4e
4c
4d
31
11
32

Fig. 4

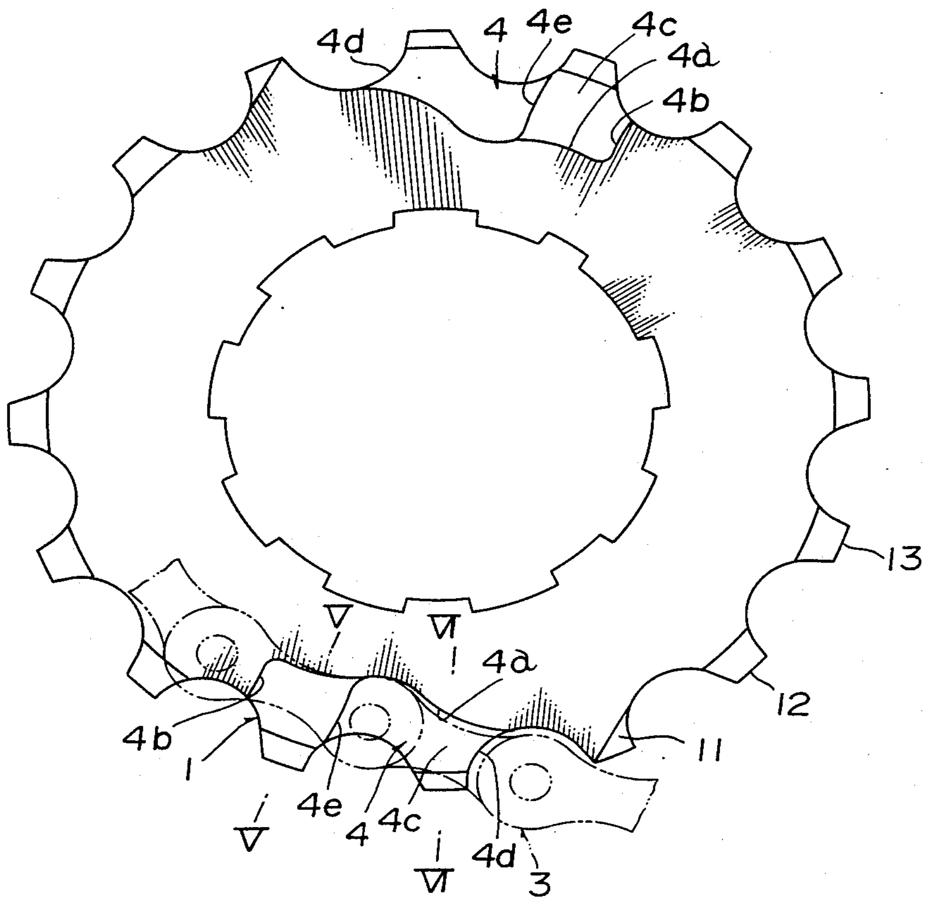


Fig.5

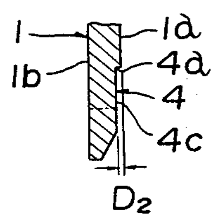


Fig.6

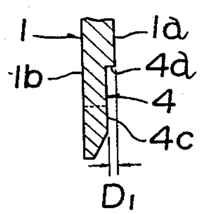


Fig.7

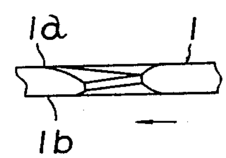


Fig.8

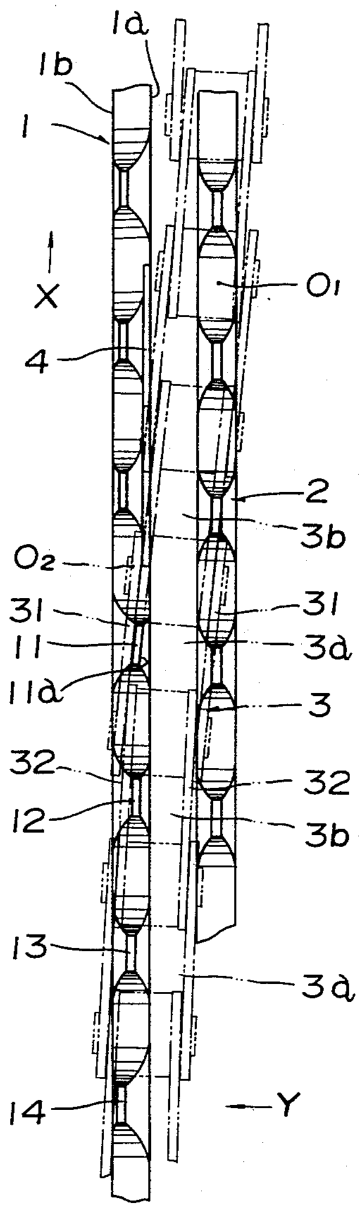
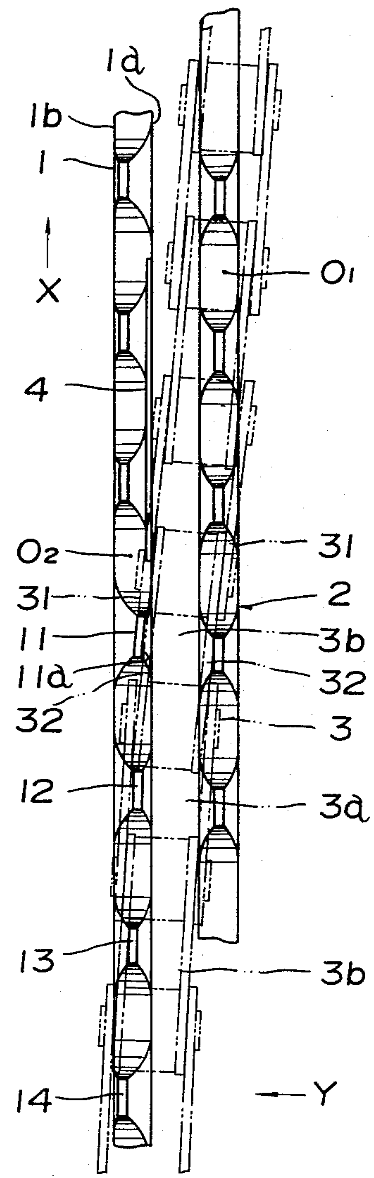

1a
1b
1
X
O1
4
2
3b
O2
31
31
11
3a
11a
3
32
32
12
3b
13
3a
14
Y

Fig.9


1a
1b
1
X
O1
4
O2
31
31
2
11
3b
11a
32
32
3
12
3a
13
3b
14
Y

MULTISTAGE SPROCKET ASSEMBLY FOR A BICYCLE

FIELD OF THE INVENTION

The present invention relates to a multistage sprocket assembly for a bicycle, and more particularly, to a multistage sprocket assembly for a bicycle, which comprises at least one larger diameter sprocket and at least one smaller diameter sprocket and is mounted on a crank or a rear hub of the bicycle so as to shift a driving chain for changing the bicycle speed.

BACKGROUND OF THE INVENTION

Conventionally, this kind of multistage sprocket assembly, as disclosed in Japanese Utility Model Publication Gazette No. Sho 55-28,617 (corresponding to U.S. Pat. No. 4,268,259), includes a smaller diameter sprocket and a larger diameter sprocket assembled such that (1) the center point between a pair of adjacent teeth at the larger diameter sprocket and the center point between a pair of adjacent teeth at the smaller diameter sprocket are positioned on the tangent extending along the chain path, (2) a distance between the aforesaid center points is an integer multiple of the chain pitch, and (3) a first tooth of the larger diameter sprocket positioned behind the center point between the adjacent teeth at the larger diameter sprocket in the rotation direction for driving the bicycle is made to be easily engageable with the driving chain, thereby improving the speed change efficiency when the driving chain is shifted from the smaller diameter sprocket to the larger diameter sprocket.

The driving chain comprises a large number of pairs of inner link plates, pair of outer link plates and pins, connected in an endless manner. An interval between the opposite surfaces of each pair of inner link plates is smaller than that between the opposite surfaces of each pair of outer link plates. In other words, each pair of the outer link plates is positioned outside the inner link plates and form a space larger in width, while each pair of the inner link plate is positioned inside the outer link plates and form a space smaller in width.

The driving chain constructed as described above is biased by a derailleur toward the larger diameter sprocket so as to be shifted thereto from the smaller diameter sprocket. During shifting, when the outer link plates of the chain correspond to the first tooth of the larger diameter sprocket, since the first tooth is the easily-engageable tooth and coincides with the chain pitch, the wider space between the outer link plates is at most fitted onto the first tooth, whereby the chain engages with the larger diameter sprocket. Even when the outer link plates correspond to the first tooth as described above, the end face of a link pin and the outer surface of the outer link plate interfere with the inside surface of the larger diameter sprocket facing toward the smaller diameter sprocket side, so that the chain may not be moved further toward the outside surface of the larger diameter sprocket, such that it will not reliably engage with the first tooth.

On the other hand, when the inner link plates correspond to the first tooth of the larger diameter sprocket, the outer link plate outside the inner link plate, in turn at the larger diameter sprocket side, interferes with the inside surface of the large diameter sprocket, whereby the inner link plate does not deviate sufficiently toward the first tooth, with the result that the space between the inner link plates is not engageable with the first tooth.

In this case, when a second tooth adjacent to the first tooth and behind in the driving rotation direction of the sprocket is made easily engageable like the first tooth, a space between the pair of outer link plates behind the inner link plates in the traveling direction thereof engages with the second tooth. However, the inner link plates behind the aforesaid outer link plates may not engage with a third tooth adjacent to the second tooth and behind in the driving rotation direction, so that even when the space between the outer link plates engages well with the second tooth, the chain may fail to engage with the third tooth and ride thereon, resulting in the chain possibly disengaging from the larger diameter sprocket.

This problem can be solved by making the third tooth easily engageable like the first and second teeth. On the other hand, in a case where the outer link plates are biased in the position at which they correspond to the first tooth, the next outer link plates corresponding to the third tooth may be caught thereby. In this case, the third tooth is not positioned corresponding to an integer multiple of the chain pitch, so that it will not smoothly engage with the chain. Hence, the outer link plates caught by the third tooth may ride on the edge of the tooth crest thereof and forcibly engage therewith, thereby creating a problem in that the speed change efficiency is diminished and also in that loud sounds are generated due to the chain suddenly falling down onto the tooth bottom.

SUMMARY OF THE INVENTION

An object of the invention is to provide a multistage sprocket assembly for a bicycle which solves the above-described problems in the conventional sprocket assembly. According to the invention, the center point between a pair of adjacent teeth at the smaller diameter sprocket and the center point between a pair of adjacent teeth at the larger diameter sprocket are positioned on the tangent line extending along a moving path of the chain when the chain is being shifted from the smaller diameter sprocket to the larger diameter sprocket and a distance between these center points is an integer multiple of the chain pitch, so that the chain is adapted to always smoothly shift from the former sprocket to the latter.

The multistage sprocket assembly of the invention comprises at least one larger diameter sprocket and at least one smaller diameter sprocket, wherein the sprockets are assembled such that the center point between a pair of adjacent teeth at the larger diameter sprocket and the center point between a pair of adjacent teeth at the smaller diameter sprocket are positioned on a tangent extending along the moving path of the driving chain when being shifted from the smaller diameter sprocket engaging therewith to the larger diameter sprocket. The distance between these center points is substantially an integer multiple of the pitch of the chain; and the larger diameter sprocket is provided at its inside surface thereof facing the smaller diameter sprocket and at a position corresponding to the moving path of the chain guide portion allowing the chain to deviate toward the larger diameter sprocket.

In addition, in the present invention, the terminology "distance equal to an integer multiple of the chain pitch" includes the distance between the center points

01 and and 02 equal to an integer multiple of the chain pitch and also a distance somewhat smaller than the chain pitch.

Accordingly, in the present invention, the chain, when shifted from the smaller diameter sprocket to the larger diameter sprocket, can be reliably biased a predetermined amount toward the outside surface of the larger diameter sprocket along the chain guide portion provided at the inside surface of the larger diameter sprocket facing the smaller diameter sprocket. Hence, when the outer link plate of the chain corresponds in position to the first tooth positioned behind the center point between a pair of adjacent teeth in the driving rotation direction, the space between the outer link plates can always reliably engage with the first tooth. Moreover, even when the inner link plate corresponds in position to the first tooth, a space between the outer link plates adjacent to and behind the inner link plates in the traveling direction thereof can reliably engage with the second tooth behind the first tooth in the driving rotation direction of the sprocket.

Also, when the outer link plates engage with the first tooth, the next outer link plates adjacent to the inner link plate behind the former outer link plates in the traveling direction thereof are prevented from riding on a third tooth behind the second tooth in the driving rotation direction of the larger diameter sprocket.

The present invention is further characterized in that at least two teeth among the plurality of teeth of the larger diameter sprocket are speed change teeth with which the chain can easily engage when being shifted from the smaller diameter sprocket to the larger diameter sprocket. These speed change teeth include the first tooth positioned behind the center point between the adjacent teeth at the larger diameter sprocket in the driving rotation direction thereof and one other tooth, with all other teeth of the larger diameter sprocket being formed such that the chain cannot easily engage with them thereby enabling the chain to be shifted to the larger diameter sprocket always at the first tooth thereof in consideration of the relationship with chain pitch. Accordingly, the chain is shifted without mistake and the speed change efficiency is improved.

The present invention is still further characterized in that the speed change teeth include a first tooth, a second tooth, and a third tooth and all other teeth are formed such that they do not easily engage with the chain. Furthermore, the first tooth is provided with a chain guide surface through which the chain, when shifted from the smaller diameter sprocket to the larger diameter sprocket, can be guided in a direction away from the smaller diameter sprocket, that is, axially outwardly of the larger diameter sprocket, with the second tooth being positioned axially outwardly of the larger diameter sprocket with respect to the first tooth and the third tooth similarly with respect to the second tooth.

Thus, the present invention can improve the speed change efficiency, prevent the outer link plate from being caught by the third tooth, and eliminate generation of sounds when the chain engages therewith.

The above and further objects and novel features of the invention will be more fully apparent from the following detailed description when the same is read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view of a first embodiment of a multistage sprocket assembly according to the invention;

FIG. 2 is a partially omitted developed view of FIG. 1 viewed from below;

FIG. 3 is a developed view corresponding to FIG. 2, in which a driving chain is shifted at a position different from that in FIG. 2 with respect to the sprockets;

FIG. 4 is a front view of a larger diameter sprocket only;

FIG. 5 is a sectional view taken on line V—V in FIG. 4;

FIG. 6 is a sectional view taken on line VI—VI in FIG. 4;

FIG. 7 is an illustration of another example of a tooth formed to be not easily engageable with the chain;

FIG. 8 is a developed view of a second embodiment of the invention, corresponding to FIG. 2; and

FIG. 9 is a developed view of the FIG. 8 embodiment corresponding to FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A multistage sprocket assembly of the invention is mounted on a crank or a rear hub of the bicycle.

A first embodiment of the multistage sprocket assembly of the invention in FIG. 1 is mounted on the rear hub of the bicycle, which includes a larger diameter sprocket 1 having 16 teeth at its outer periphery and a smaller diameter sprocket 2 having 13 teeth at its outer periphery, sprockets 1 and 2 being assembled to a driving member (not shown) and spaced from each other at a predetermined interval, the driving member being rotatably supported to a driven member at the rear hub through a bearing.

Also, sprockets 1 and 2 are assembled in a relationship such that the center point 02 between a pair of adjacent teeth at larger diameter sprocket 1 and the center point 01 between a pair of adjacent teeth at smaller diameter sprocket 2 are positioned on a tangent which, as shown by the chain line in FIG. 1, extends along a moving path of a driving chain when shifted from smaller diameter sprocket 2 in engagement therewith to large diameter sprocket 1.

A distance L between centers 01 and 02 is equal to an integer multiple of the chain pitch of chain 3, and a chain guide portion 4 allowing chain 3 to deviate toward larger diameter sprocket 1 is recessed at the inside surface thereof facing smaller diameter sprocket 2 and at the position corresponding to the traveling path of chain 3 when traveling between centers 01 and 02.

Chain guide portion 4 recessed on the inside surface of sprocket 1 is preferably deep enough to prevent the inner link plate of chain 3 at the larger diameter sprocket side from riding on a first tooth 11 at larger diameter sprocket 1, first tooth 11 being positioned behind center 02 at sprocket 1 in the driving rotation direction thereof.

At least two teeth including aforesaid tooth 11 and a tooth 12 adjacent thereto and positioned rearwardly in the rotation direction of sprocket 1 are formed as speed change teeth engageable with chain 3 when shifted from smaller diameter sprocket 2 to larger diameter sprocket 1. The residual teeth except for teeth 11 and 12 are formed as non-easily-engageable teeth through which chain 3 is not shiftable.

Chain guide portion 4 is made large enough to receive therein the link plates of chain 3 positioned at the larger diameter sprocket side, so that chain 3 can deviate a predetermined amount toward outside surface 1*b* of larger diameter sprocket 1, thereby reliably engaging with first tooth 11. Chain guide portion 4 recessed as described above, is preferably deep enough to engage a space 3*a* between outer link plates 31 with first tooth 11 when outer link plates 31 corresponds to first tooth 11 as shown in FIG. 2 and to prevent inner link plate 32 of chain 3 from riding on first tooth 11 when inner link plate 32 corresponds to first tooth 11 as shown in FIG. 3. In brief, chain 3 is preferably controlled with respect to its movement with respect to larger diameter sprocket 1.

Chain guide portion 4 may alternatively be formed of a cutout, but when it is recessed, the movement of chain 3 can be controlled and a stepped portion 4*a* can receive the link plate of chain 3 when shifted.

In the first embodiment in FIG. 1 of larger diameter sprocket 1 of 16 teeth and smaller diameter sprocket 2 of 13 teeth, a distance L between centers 01 and 02 is equal to twice the pitch of chain 3 as shown by the chain line in FIG. 1.

Accordingly, chain guide portion 4 at inside surface 1*a* of larger diameter sprocket 1 is formed in the size from an initial end edge 4*b* to a termination 4*d* at sprocket 1, with initial end edge 4*b* being somewhat spaced apart from the position corresponding to center 01 between the two adjacent teeth at sprocket 2 and between center 01 and center 02 between two adjacent teeth at sprocket 1, with termination 4*d* being the tooth bottom between first tooth 11 and a tooth 10 positioned ahead of center 02 in the driving rotation direction (the direction of arrow X) of sprocket 1.

In a condition where outer link plate 31 of chain 31 corresponds to first tooth 11 as shown in FIGS. 1 and 2, at chain guide position 4 are positioned inner link plate 32 positioned ahead of outer link plate 31 in the traveling direction (in the direction of arrow Y in FIG. 1) of chain 3, part of an outer link plate 31 positioned ahead of inner link plate 32 in the traveling direction, and a link pin 33 for connecting link plates 32 and 31, with link pin 33 abutting at its end face against bottom 4*c* of recessed chain guide portion 4.

In a condition where inner link plate 32 corresponds to first tooth 11 as shown in FIG. 3, at chain guide portion 4 are positioned outer link plate 31 ahead of inner link plate 32 in the traveling direction of chain 3, part of inner link plate 32 positioned ahead of outer link plate 31, and a link pin 33 for connecting link plates 31 and 32, with the end face of link pin 33 and outer link plate 31 abutting against the bottom of recessed chain guide portion 4.

In chain guide portion 4, a depth D1 (in FIG. 6) in a range from an intermediate portion (i.e., between initial and 4*b* and termination 4*d*) to the termination 4*d* is made larger than depth D2 (in FIG. 5) in a range from initial end edge 4*b* to the intermediate portion.

Also, in the first embodiment, a stepped portion 4*e* is provided at the intermediate portion of guide portion 4 so as to stepwise change the depth thereof, but chain guide portion 4 may alternatively be inclined throughout its entire length.

Since teeth facing chain guide portion 4 each are reduced in thickness to an extent corresponding to the depth of guide portion 4, it is preferable to make these teeth larger in circumferential width than the other teeth as shown in FIGS. 1 and 4, thereby restricting the lowering of strength of these reduced-thickness teeth.

All of the teeth except for first and second teeth 11 and 12 are made non-easily-engageable. The non-easily-engageable teeth, as shown in FIGS. 2 and 3, are each chamfered at their inner surface facing smaller diameter sprocket 2, or, as shown in FIG. 7, inclined forwardly in the driving rotation direction (in the direction of arrow X) and reversely to smaller diameter sprocket 2, that is, toward the outside surface of larger diameter sprocket 1 with respect to the center line thickness between inside surface 1*a* and outside surface 1*b* of larger diameter sprocket 1, thereby being made difficult to engage with chain 3.

In addition, first and second teeth 11 and 12 are not made non-easily-engageable because chain 3 is intended to reliably engage with first tooth 11, and spaces 3*a* and 3*b* between the link plates of chain 3 in engagement with tooth 11 are to reliably engage with second tooth 12, whereby first and second teeth 11 and 12 are preferably easily engageable with chain 3.

Also, a distance between the adjacent teeth and on the pitch circle of respective sprockets 1 and 2 is made larger by a predetermined distance than an outer diameter of a roller of chain 3. Accordingly, distance L between centers 01 and 02 is smaller than an integer multiple of the chain pitch. In other words, when sprockets 1 and 2 are mounted on the rear hub, a driving force from pedaling is transmitted from chain 3 to sprocket 1 or 2, whereby when chain 3 is shifted from sprocket 2 to sprocket 1, the roller at the smaller diameter sprocket 2 side abuts against the rear surface of a tooth ahead of the roller in the driving rotation direction of sprocket 2, and the roller moving toward larger diameter sprocket 1 and caught by the tooth thereof abuts against the front surface of first tooth 11 in the driving rotation direction of sprocket 1, whereby when both sprockets 1 and 2 are aligned, distance L is somewhat smaller than an integer multiple of the chain pitch. In addition, when the distance between the adjacent teeth on the pitch circle corresponds to the outer diameter of the roller, distance L is made equal to an integer multiple of the chain pitch.

When chain 3 is shifted from smaller diameter sprocket 2 to larger diameter sprocket 1 by a rear derailleur, the engagement of chain 3 with sprockets 1 and 2 will be described in accordance with FIGS. 1 through 3.

In FIGS. 1 and 3, when chain 3 in engagement with smaller diameter sprocket 2 is displaced by the rear derailleur to larger diameter sprocket 1, chain 3 in part positioned ahead in the driving rotation direction (in the direction of arrow X) remains at smaller diameter sprocket 2 and the same positioned at the rear derailleur operation side reaches the lateral side of sprocket 1 to thereby be inclined and biased toward sprocket 1 as shown in FIGS. 2 and 3.

Also, chain guide portion 4 is provided on the traveling path of chain 3 when traveling between centers 01 and 02, so that chain 3 travels a predetermined amount toward the outside surface of sprocket 1, thereby reliably engaging with first tooth 11 thereof.

Since chain guide portion 4 is recessed to an extend such that inner link plate 32 of chain 3 at the larger diameter sprocket 1 side does not ride on first tooth 11, when inner link plate 32 is positioned corresponding thereto, outer link plate 31 abuts against termination 4*d* of chain guide portion 4 as shown in FIGS. 3 and chain 3 is restricted from moving toward the outside surface,

thereby preventing inner link plate 32 from riding on first tooth 11.

Also, chain 3 can inevitably engage only with first or second tooth 11 or 12 because all other teeth are non-easily-engageable teeth, thereby ensuring smooth shifting of chain 3.

Alternatively, as shown in a second embodiment of the invention illustrated in FIGS. 8 and 9, a third tooth 13 positioned behind second tooth 12 in the driving rotation direction of sprocket 1 may also not be a non-easily-engageable tooth but rather a speed change tooth engageable with chain 3.

In FIGS. 8 and 9, all of teeth 14 except for the first through third teeth 11 through 13 at larger diameter sprocket 1 deviate axially outwardly thereof, that is, reversely to sprocket 2, so as to render difficult any engagement thereof with chain 3. First through third teeth 11 through 13 are displaced axially inwardly of sprocket 1, that is, toward sprocket 2, thereby being easily engageable with chain 3. Moreover, first tooth 11 is provided with a chain guide surface 11*a* for guiding therethrough chain 3 reversely to sprocket 2. Second tooth 12 is displaced reversely thereto with respect to first tooth 11, and likewise third tooth 13 with respect to second tooth 12, so that second tooth 12 is easily engageable with chain 3 subsequently to first tooth 11, with third tooth 13 being not difficult but not-easier to engage with chain 3 than second tooth 12.

In the above-mentioned construction, chain guide surface 11*a*, as shown in FIGS. 8 and 9, is inclined rearwardly in the driving rotation direction of larger diameter sprocket 1 and reversely to smaller diameter sprocket 2 with respect to the center line of thickness of sprocket 1. Alternatively, chain guide surface 11*a* may be formed such that first tooth 11 is parallel to the aforesaid center line and cutout at a portion disposed rearward in the driving rotation direction of sprocket 1 and facing smaller diameter sprocket 2, for example, at a portion from the bottom to the crest of the tooth.

When chain 3 is shifted from smaller diameter sprocket 2 to larger diameter sprocket 1, space 3*a* between outer link plates 31 first engages with first tooth 11. Therefore, first tooth 11 is made to be most easily engageable with chain 3. Second tooth 12 is also made such that it can easily engage with chain 3; this is made possible by providing a narrow space 3*b* between inner link plates 32 behind wide space 3*a*. Narrow space 3*b* is easily engageable with second tooth 12, and, when inner link plates 32 are biased at the position corresponding to first tooth 11 and first tooth 11 cannot catch space 3*a*, second tooth 12 is adapted to catch space 3*a*. Also, when second tooth 12 catches wide space 3*a*, narrow space 3*b* adjacent thereto is adapted to easily engage with third tooth 13, such that third tooth 13 is made easily engageable with chain 3.

In addition, the displacement of third tooth 13 toward smaller diameter sprocket 2 is reduced more than that of second tooth 12 because, when inner link plates 32 are biased at the position corresponding to second tooth 12 so that first and second teeth 11 and 12 cannot catch wide space 3*a*, the outer link plate is prevented from riding on third tooth 13.

In the above-described construction, in a condition in which chain 3 is shifted from smaller diameter sprocket 2 to larger diameter sprocket 1, when first tooth 11 corresponds to outer link plate 31, a distance between centers 01 and 02 of an interval between the two adjacent teeth at sprockets 1 and 2 is substantially an integer multiple of the chain pitch so that the roller of chain 3 is biased to be positioned corresponding to center 02 between the adjacent teeth at sprocket 1, and first tooth 11 is easily engageable with chain 3, resulting in that wide space 3*a* between outer link plates 31 adjacent to the roller smoothly engages with first tooth 11.

In this condition, since second tooth 12 behind first tooth 11 in the driving rotation direction of sprocket 1 also is an easily-engageable tooth, space 3*b* between inner link plate 32 behind outer link plate 31 in the traveling direction and adjacent thereto smoothly engages with second tooth 12, thereby quickly shifting chain 3 to sprocket 1. Also, outer link plate 31 behind inner link plate 32 in the traveling direction can reliably engage with third tooth 13 behind second tooth 12. In other words, tooth 13 is easily engageable with chain 3 and first tooth 11 is provided with a chain guide surface 11*a*, so that chain 3, when shifted from sprocket 2 to sprocket 1, can be displaced reversely to sprocket 2 more than when guide surface 11*a* is not provided, and correspondingly second tooth 12 is displaced reversely to sprocket 2 and third tooth 13 with respect to second tooth 12, thereby reliably preventing outer link plate 31 from riding on third tooth 13. Also, chain 3 can smoothly engage with third tooth 13 without riding thereon and eliminate sounds generated when engaging with chain 3.

On the other hand, when inner link plate 32 corresponds in position to first tooth 11 when chain 3 is being shifted, space 3*b* between inner link plates 32 does not engage with first tooth 11, but a space 3*a* between the next outer link plates 31 positioned behind inner link plates 32 in the traveling direction (the direction of arrow Y) engages with second tooth 12. In this condition, the next inner link plates 32 positioned behind outer link plates 31 in the traveling direction correspond to third tooth 13. Since third tooth 13 is a speed change tooth, space 3*b* between inner link plates 32 engages with third tooth 13, whereby chain 3 is quickly shifted to larger diameter sprocket 1.

Alternatively, the multistage sprocket assembly may comprise three or more sprockets and may be used for a crank means at the bicycle.

As is apparent from the above, the present invention has at least one larger diameter sprocket 1 and at least one smaller diameter sprocket 2 assembled in a relationship such that a center 02 between a pair of adjacent teeth at sprocket 1 and a center 01 between a pair of adjacent teeth at sprocket 2 are positioned on a tangent to the chain path. Also, according to the invention, the distance between centers 01 and 02 is substantially an integer multiple of the chain pitch, and a chain guide portion 4 is provided to allow chain 3 to deviate axially outwardly of sprocket 1 at the inside surface thereof facing sprocket 2 and corresponding to the traveling path of chain 3 when traveling between centers 01 and 02, whereby, when chain 3 is shifted from smaller diameter sprocket 2 to larger diameter sprocket 1, the chain can smoothly engage with sprocket 1 and chain guide portion 4 can displace by a predetermined amount axially outwardly of sprocket 1. Hence, the space between outer link plates 31 can reliably engage with the first tooth behind center 02, and also inner link plates 32, even when corresponding to first tooth 11 but not engaging therewith, never rides on first tooth 11, thereby reliably engaging outer link plates 31 behind inner link plate 32 in the traveling direction. Also, inner link plates 32 behind outer link plates 31 in the traveling direction

can reliably engage with third tooth **13** positioned behind second tooth **12** in the driving rotation direction of sprocket **1**.

Although several embodiments have been described above, they are merely exemplary of the invention and not to be construed as limiting, the invention being defined solely by the appended claims.

What is claimed is:

1. A multistage sprocket assembly for a bicycle, said sprocket assembly comprising:

at least one large diameter sprocket having at its outer periphery a plurality of teeth; and at least one smaller diameter sprocket having at its outer periphery a plurality of teeth smaller in number than said plurality of teeth of said larger diameter sprocket, a pair of adjacent teeth of said larger diameter sprocket having a first center point therebetween and a pair of adjacent teeth of said smaller diameter sprocket having a second center point therebetween, said first center point and said second center point being positioned on a tangent line extending along a traveling path between said smaller diameter sprocket and said larger diameter sprocket of a driving chain in engagement with said smaller diameter sprocket when said chain is being shifted from said smaller diameter sprocket to said larger diameter sprocket, a distance between said first center point and said second center point being substantially an integer multiple of a pitch between adjacent links of said chain, and said larger diameter sprocket comprising chain guide means, provided at its inside surface facing said smaller diameter sprocket and at a position of said larger diameter sprocket corresponding to said traveling path of said chain when traveling between said first center point and said second center point, for allowing said chain to move at said chain guide means farther from said smaller diameter sprocket and closer toward said inside surface of said larger diameter sprocket than at other portions of said larger diameter sprocket.

2. A multistage sprocket assembly according to claim **1**, wherein at least two teeth among said plurality of teeth of said larger diameter sprocket are speed change teeth which include means for facilitating engagement with said chain when said chain is being shifted from said smaller diameter sprocket to said larger diameter sprocket, said speed change teeth including a first tooth positioned behind said first center point in a driving rotation direction of said larger diameter sprocket, all other teeth of said plurality of teeth of said larger diameter sprocket including means for inhibiting engagement thereof with said chain when said chain is being shifted from said smaller diameter sprocket to said larger diameter sprocket.

3. A multistage sprocket assembly according to claim **2**, wherein said speed change teeth comprise a first tooth, a second tooth adjacent to and behind said first tooth in said driving rotation direction of said larger diameter sprocket, and a third tooth adjacent to and positioned behind said second tooth in said driving rotation direction of said larger diameter sprocket.

4. A multistage sprocket assembly according to claim **3**, wherein said first tooth includes a chain guide surface for guiding said chain in a direction away from said smaller diameter sprocket when said chain is being shifted from said smaller diameter sprocket to said larger diameter sprocket, said second tooth is positioned farther from said smaller diameter sprocket than said first tooth is positioned from said smaller diameter sprocket, and said third tooth is positioned farther from said smaller diameter sprocket than said second tooth is positioned from said smaller diameter sprocket.

5. A multistage sprocket assembly according to claim **1**, wherein said chain guide means comprises a chain guide portion recessed at said surface of said larger diameter sprocket facing said smaller diameter sprocket, said recess having a sufficient depth at a side of said first center point to prevent an outside link plate of said chain from riding on a tooth positioned behind said first center point in said driving rotation direction of said larger diameter sprocket.

6. A multistage sprocket assembly according to claim **1**, wherein said chain guide means comprises a chain guide portion formed of a cutout in said inside surface of said larger diameter sprocket.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : B1 4,889,521

DATED : May 9, 1995

INVENTOR(S) : Masashi Nagano

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Columns 3 and 4:

Claims 24-28, line 2 in each claim, after "wherein" insert--said chain guide means includes a chain guide portion recessed at said surface of said larger diameter sprocket, and wherein any--.

Signed and Sealed this

Seventeenth Day of October, 1995

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

US004889521B1

REEXAMINATION CERTIFICATE (2567th)

United States Patent [19]

[11] B1 4,889,521

Nagano

[45] Certificate Issued May 9, 1995

[54] **MULTISTAGE SPROCKET ASSEMBLY FOR A BICYCLE**

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[73] Assignee: **Shimano Industrial Company Limited**, Sakai, Japan

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Reexamination Certificate for:

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Filed:	**Oct. 24, 1988**

[30] **Foreign Application Priority Data**

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Jun. 4, 1988	[JP]	Japan	63-74583

[51] **Int. Cl.**[6] **F16H 63/00**
[52] **U.S. Cl.** **474/164**
[58] **Field of Search** 474/160, 162, 164, 152, 474/155–157; 74/594.2; 29/893

[56] **References Cited**

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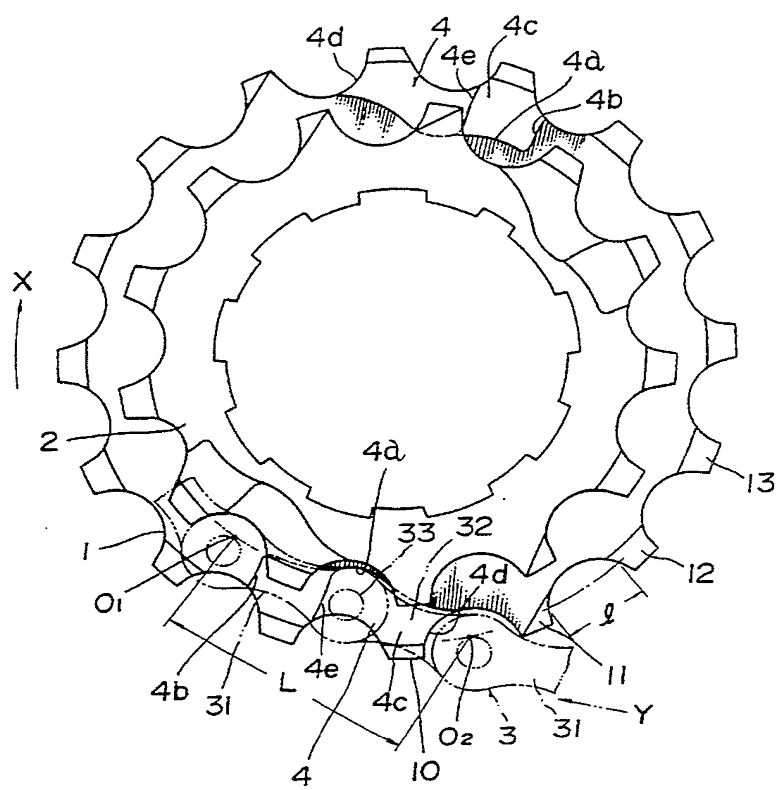
Primary Examiner—Michael Powell Buiz

[57] **ABSTRACT**

A multistage sprocket assembly is provided which includes at least one larger diameter sprocket and at least one smaller diameter sprocket assembled in a relationship such that the center point between a pair of adjacent teeth at the larger diameter sprocket and the center point between a pair of adjacent teeth at the smaller diameter sprocket are positioned on a tangent extending along the chain path when the chain is being shifted from the smaller diameter sprocket to the larger diameter sprocket. The distance between both the center points is equal to an integer multiple of the chain pitch. A chain guide portion is provided at the inside surface of the larger diameter sprocket and at a position corresponding to a moving path of a driving chain traveling between the aforesaid center points for allowing the chain to move axially of the sprocket assembly slightly toward the larger diameter sprocket during shifting.



REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1–6** is confirmed.

New claims **7–35** are added and determined to be patentable.

7. A multistage sprocket assembly for a bicycle, said sprocket assembly comprising:

at least one large diameter sprocket having at its outer periphery a plurality of teeth; and at least one smaller diameter sprocket having at its outer periphery a plurality of teeth smaller in number than said plurality of teeth of said larger diameter sprocket, a pair of adjacent teeth of said larger diameter sprocket having a first center point therebetween and a pair of adjacent teeth of said smaller diameter sprocket having a second center point therebetween, said first center point and said second center point being positioned on a tangent line extending along a traveling path between said smaller diameter sprocket and said larger diameter sprocket of a driving chain in engagement with said smaller diameter sprocket when said chain is being shifted from said smaller diameter sprocket to said larger diameter sprocket, a distance between said first center point and said second center point being substantially an integer multiple of a pitch between adjacent links of said chain, and said larger diameter sprocket comprising chain guide means, provided at its inside surface facing said smaller diameter sprocket and at a position of said larger diameter sprocket corresponding to said traveling path of said chain when traveling between said first center point and said second center point, for allowing said chain to move at said chain guide means farther from said smaller diameter sprocket and closer toward said inside surface of said larger diameter sprocket than at other portions of said larger diameter sprocket, said chain guide means comprising a chain guide portion recessed at said surface of said larger diameter sprocket, said recessed chain guide portion spanning a plurality of adjacent teeth.

8. The multistage sprocket assembly according to claim 7 wherein said recessed chain guide portion comprises:

a first edge portion originating between said pair of adjacent teeth of said larger diameter sprocket having said first center point therebetween; and

a second edge portion originating between another pair of adjacent teeth of said larger diameter sprocket.

9. The multistage sprocket assembly according to claim 7 including a speed change tooth which includes means for facilitating engagement with said chain when said chain is being shifted from said small diameter sprocket to said larger diameter sprocket, said speed change tooth being positioned behind said first center point in a driving rotation direction of said larger diameter sprocket.

10. The multistage sprocket assembly according to claim 9 wherein said recessed chain guide portion comprises:

a first edge portion originating between said pair of adjacent teeth of said larger diameter sprocket having said first center point therebetween; and a second edge portion originating between another pair of adjacent teeth of said larger diameter sprocket.

11. The multistage sprocket assembly according to claim 9 wherein said recessed chain guide portion comprises:

an initial end edge spaced apart from a position corresponding to said second center point between said pair of adjacent teeth of said smaller diameter sprocket and between said second center point and said first center point between said pair of adjacent teeth of said larger sprocket.

12. The multistage sprocket assembly according to claim 7 wherein said plurality of teeth spanned by said recessed chain guide portion are recessed by an amount equal to said recessed chain guide portion.

13. The multistage sprocket assembly according to claim 7 wherein said plurality of teeth spanned by said recessed chain guide portion are recessed along their entire inner surface facing said smaller diameter sprocket by an amount equal to said corresponding recessed chain guide portion.

14. The multistage sprocket assembly according to claim 13 wherein said plurality of teeth spanned by said recessed chain guide portion have a larger circumferential width than other teeth on said larger sprocket.

15. The multistage sprocket assembly according to claim 14 wherein said plurality of teeth spanned by said recessed chain guide portion have a larger circumferential width than non-recessed teeth on said larger sprocket.

16. The multistage sprocket assembly according to claim 15 wherein said plurality of teeth spanned by said recessed chain guide portion have a larger circumferential width than any other teeth on said larger sprocket not spanned by another recessed chain guide portion.

17. The multistage sprocket assembly according to claim 7 wherein said recessed chain guide portion includes a stepped portion at an intermediate portion thereof for changing the depth of the recessed chain guide portion in a driving rotation direction of said larger sprocket.

18. The multistage sprocket assembly according to claim 7 wherein said recessed chain guide portion is inclined throughout its entire length for changing the depth of the recessed chain guide portion in a driving rotation direction of said larger sprocket.

19. The multistage sprocket assembly for a bicycle, said sprocket assembly comprising:

at least one large diameter sprocket having at its outer periphery a plurality of teeth; and at least one smaller diameter sprocket having at its outer periphery a plurality of teeth smaller in number than said plurality of teeth of said larger diameter sprocket, a pair of adjacent teeth of said larger diameter sprocket having a first center point therebetween and a pair of adjacent teeth of said smaller diameter sprocket having a second center point therebetween, said first center point and said second center point being positioned on a tangent line extending along a traveling path between said smaller diameter sprocket and said larger diameter sprocket of a driving chain in engagement with said smaller diameter sprocket when said chain is being shifted from said smaller diameter sprocket to said larger diameter sprocket, a distance between said

first center point and said second center point being substantially an integer multiple of a pitch between adjacent links of said chain, wherein, when a portion of said driving chain is in engagement with said larger diameter sprocket, a sprocket tooth extends into each link of said portion of said driving chain engaging said larger diameter sprocket and said larger diameter sprocket comprising chain guide means, provided at its inside surface facing said smaller diameter sprocket and at a position of said larger diameter sprocket corresponding to said traveling path of said chain when traveling between said first center point and said second center point, for allowing said chain to move at said chain guide means farther from said smaller diameter sprocket and closer toward said inside surface of said larger diameter sprocket than at other portions of said larger diameter sprocket.

20. The multistage sprocket assembly according to claim 19 wherein said chain guide means includes a recessed chain guide portion spanning a plurality of said teeth of said larger diameter sprocket, said recessed chain guide portion comprising:

a first edge portion originating between said pair of adjacent teeth of said larger diameter sprocket having said first center point therebetween; and

a second edge portion originating between another pair of adjacent teeth of said larger diameter sprocket.

21. The multistage sprocket assembly according to claim 19 including a speed change tooth which includes means for facilitating engagement with said chain when said chain is being shifted from said small diameter sprocket to said larger diameter sprocket, said speed change tooth being positioned behind said first center point in a driving rotation direction of said larger diameter sprocket.

22. The multistage sprocket assembly according to claim 21 wherein said chain guide means includes a chain guide portion recessed at said surface of said larger diameter sprocket, said recessed chain guide portion comprising:

a first edge portion originating between said pair of adjacent teeth of said larger diameter sprocket having said first center point therebetween; and a second edge portion originating between another pair of adjacent teeth of said larger diameter sprocket.

23. The multistage sprocket assembly according to claim 21 wherein said chain guide means includes a chain guide portion recessed at said surface of said larger diameter sprocket, said recessed chain guide portion comprising:

an initial end edge spaced apart from a position corresponding to said second center point between said pair of adjacent teeth of said smaller diameter sprocket and between said second center point and said first center point between said pair of adjacent teeth of said larger sprocket.

24. The multistage sprocket assembly according to claim 19 wherein teeth spanned by said recessed chain guide portion are recessed by an amount equal to said recessed chain guide portion.

25. The multistage sprocket assembly according to claim 19 wherein teeth spanned by said recessed chain guide portion are recessed along their entire inner surface facing said smaller diameter sprocket by an amount equal to said corresponding recessed chain guide portion.

26. The multistge sprocket assembly according to claim 25 wherein teeth spanned by said recessed chain guide portion have a larger circumferential width than other teeth on said larger sprocket.

27. The multistage sprocket assembly according to claim 26 wherein teeth spanned by said recessed chain guide portion have a larger circumferential width than non-recessed teeth on said larger sprocket.

28. The multistage sprocket assembly according to claim 27 wherein teeth spanned by said recessed chain guide portion have a larger circumferential width than any other teeth on said larger sprocket not spanned by another recessed chain guide portion.

29. The multistage sprocket assembly according to claim 19 wherein said chain guide means includes a chain guide portion recessed at said surface of said larger diameter sprocket, said recessed chain guide portion including a stepped portion at an intermediate portion thereof for changing the depth of the recessed chain guide portion in a driving rotation direction of said larger sprocket.

30. The multistage sprocket assembly according to claim 19 wherein said chain guide means includes a chain guide portion recessed at said surface of said larger diameter sprocket, said recessed chain guide portion being inclined throughout its entire length for changing the depth of the recessed chain guide portion in a driving rotation direction of said larger sprocket.

31. A multistage sprocket assembly for a bicycle, said sprocket assembly comprising:

at least one large diameter sprocket having at its outer periphery a plurality of teeth; and at least one smaller diameter sprocket having at its outer periphery a plurality of teeth smaller in number than said plurality of teeth of said larger diameter sprocket, a pair of adjacent teeth of said larger diameter sprocket having a first center point therebetween and a pair of adjacent teeth of said smaller diameter sprocket having a second center point therebetween, said first center point and said second center point being positioned on a tangent line extending along a traveling path between said smaller diameter sprocket and said larger diameter sprocket of a driving chain in engagement with said smaller diameter sprocket when said chain is being shifted from said smaller diameter sprocket to said larger diameter sprocket, a distance between said first center point and said second center point being substantially an integer multiple of a pitch between adjacent links of said chain, and said larger diameter sprocket comprising chain guide means, provided at its inside surface facing said smaller diameter sprocket and at a position of said larger diameter sprocket corresponding to said traveling path of said chain when traveling between said first center point and said second center point, for allowing said chain to move at said chain guide means farther from said smaller diameter sprocket and closer toward said inside surface of said larger diameter sprocket than at other portions of said larger diameter sprocket, said chain guide means including:

a surface of said larger diameter sprocket which forms a recess below a first tooth located between said first center point and said second center point; and

a surface of a second tooth adjacent to and behind said first tooth in the direction of rotation of said larger diameter sprocket and facing said smaller diameter sprocket that is further away from said smaller diameter sprocket than a corresponding surface of a third tooth adjacent to and behind said second tooth in the direction of rotation of said larger diameter sprocket.

32. The multistage sprocket assembly according to claim 31 wherein said recessed surface of said larger diameter sprocket includes a stepped portion at an intermediate portion thereof for changing the depth of the recess in a driving rotation direction of said larger sprocket.

33. The multistage sprocket assembly according to claim 31 wherein said first tooth is recessed along its entire inner surface facing said smaller diameter sprocket by an amount equal to said recess below said first tooth.

34. The multistage sprocket assembly according to claim 33 wherein said surface of said larger diameter sprocket corresponding to said travelling path of said chain is recessed.

35. The multistage sprocket assembly according to claim 34 wherein said recessed surface of said larger diameter sprocket includes a stepped portion at an intermediate portion thereof for changing the depth of the recess in a driving rotation direction of said larger sprocket.

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